PROGRESS IN COLOR, COLORANTS AND COATINGS

available online @ www.pccc.icrc.ac.ir

Prog. Color Colorants Coat. 12 (2019), 251-261

Ministry of Science, Research and Technology
Institute for Color Science and Technology

Recognition of Sequence of Print and Ink Strokes: Investigation the Effect of Handwriting Pressure, Hue of Ink, Printer and Paper Type

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ARTICLE INFO

Article history:
Received: 14 Apr 2019
Final Revised: 21 Jun 2019
Accepted: 22 Jun 2019
Available online: 07 Jul 2019

Keywords:
Forensic science
Document examination
Intersecting lines
Digital microscope
Sequence of strokes.

ABSTRACT

By introducing of digital techniques, forensic document examiners has been encouraged to work with better accuracy in non-destructive ways. The aim of this study was to present a non-destructive, accessible, economic (affordable), user friendly, portable, useful and easy technique for specifying the order of crossing lines of ink stroke and printed text. The intersections of LaserJet and Inkjet prints in different colors and brands under various handwriting pressures and papers were examined with a digital microscope. The 2414 exemplars were prepared on two types of A4 papers. For the Inkjet printer, the sequence of printed text and ink stroke cannot be recognized. For LaserJet printer, the results showed the outcomes indicated using digital microscope is a good option in defining the sequence of pen-ink strokes in different colors and black toner in most examples. In the blue, black and red hues, the sequence of print and ink is recognizable in most cases. For green color, no specific results were observed. Prog. Color Colorants Coat. 12 (2019), 251-261© Institute for Color Science and Technology.

1. Introduction

In the last three decades, a significant increase in the number of documents prepared with the use of printers, copiers, and multifunction systems has been noted. Widespread access and simplicity of the use of these systems make it simple to create fraudulent documents using a toner (e.g., dry or liquid) and/or ink. As with most materials associated with criminal cases, it may be necessary to collect various analytical data which may help in investigating the process [1]. Printing technology developments have exacerbated the problem of document counterfeiting, prompting the need for analytical techniques for better characterize of inks for forensic analysis and comparisons [2]. In other words, it is easy to change a printed document for malicious aims because of the recent technical developments [3]. Document labs are often challenged with the enquiry, whether the content of a document such as a receipt, legal agreement, etc., is changed through three common ways. They could be produced by adding a new text, clearing some words and intersecting lines which is a result of overwritten entries [4]. Accordingly, document authenticity plays an important role in forensic science where documents are disagreement in a court of law. In fact, "questioned document examination" has become an important discipline within forensic science. "Questioned document examination" deals with scientific techniques that can provide evidences about a doubtful or questionable document [3].

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Most forgeries are categorized into three main groups, i.e. (i) clearing some texts, (ii) adding some new texts and (iii) intersecting lines [5, 6]. A common problem in question documents is to determine the sequence of intersecting lines [7, 8]. Document experts often confront with the problem of determining the genuineness documents through recognizing the sequence of the inked strokes [9]. Intersections are formed by the writing of ink; they can also be formed by printing text, paper fold, typewriting, etc [10].

Various destructive and nondestructive methods are suggested for finding the sequence of the strokes. Destructive methods are typically electrospray-mass spectrometry (ESI-MS) (minimally destructive) [11], scanning electron microscopy (SEM) [12]. Nondestructive methods are atomic force microscopy (AFM) [13, 14], attenuated total reflectance–fourier transform infrared (ATR-FTIR) [15], lifting techniques [16], physicochemical analysis [17], spectrophotometry, microscopic [18] and photographic [19] techniques, indented impression, electrostatic techniques [7], optical examination [18, 20, 21], field emission scanning electron microscope with energy-dispersive X-ray spectroscopy (FE-SEM-EDS) [22], UV–Vis spectroscopy and chemometrics [23].

Among preferred methods to recognize document forgery, optical examinations are non-destructive, accessible, inexpensive and simple in nature [20]. Moreover, it seems that the combination of optical and microscopic methods for examining some properties of ink such as color, absorption, luminescence and gloss of ink lines are favorable and result showed to be effective in certain cases [24, 25]. Montani *et al.* examined the capability of digital microscopy to specify the line crossing sequences between pens and Laser printers [19]. They proved that when ink line is over printed text, a light reflection could be seen in all specimens, although this is never shown in other sequence situations. For instance, where no shiny aspect is observed at the crossing, the experts should not conclude categorically as a Rollerball pen–toner line sequence. Ozbek *et al.* studied the crossing between printer and pen ink texts. Their results specified whenever printer ink was on top of pen ink, for crossings involving both LaserJet and Inkjet printers, a double layer of ink is formed [24]. In return, when pen ink line is over printer ink line, pen ink shows a tendency to penetrate through printer ink which results in ink mixing. Additionally, the Inkjet ink showed greater penetration than toner, which can be explained by printing procedure and liquid nature of the inkjet ink. Singla *et al.* analyzed the order of writing of ballpoint pen texts and correctable typewriter ribbon marks and used a stereomicroscope in which the beam of incident light locates at an angle of about 45 to the plane of the paper [26]. Planty also used stereomicroscope to find the sequence of laser printed texts with the ballpoint ink texts [27]. Seitz *et al.* [28] and Aginsky [29] utilized microscopic techniques for determining the order of writing of laser printing and ballpoint pen texts when there is no line-crossing. It was successfully specified the order of writing impressions with laser printing using a machine used within forensics for document examination called ESDA [30].

At the present work, the effects of various parameters such as hue, brand of ink, handwriting pressure, type of printer and paper on recognition of the sequence of print and ink strokes are investigated. The microscopic images obtained by using a Dino-lite digital were selected as a non-destructive technique which is accessible, economic and easy to use.

2. Materials and Methods

The samples consisting of intersecting lines of pencil and printed text were prepared with two types of printers of dry toner LaserJet model HP 1320 series and Inkjet EPSON P50 series and four different colors (black, blue, red and green) pens as well as different brands. These two widely used of printers benefit from different mechanisms of print production. In the LaserJet printer, toner particles locate on paper and the film is formed through fusing and heating [31]. In Inkjet models, the ink tends to spread along the paper fibers and penetrate into the bulk of the paper. The water-based ink actually depends on the penetration and absorption for its drying mechanism. Some evaporation of water is taking place, but this drying mechanism is often very slow [32].

All the samples were prepared on A4 size white sheet both uncoated (JK Paper LTD Company) and coated (glossy) papers. The details of the used materials are listed in Table 1.

Table1: Materials specifications.

Number	Type of writing instruments	Model of writing instruments	Writing instruments	Hue
1	LaserJet printer	HP 1320 series		Black
2	Inkjet printer	EPSON P50		Black
3	Ballpoint Pen	Zebra Z-1		Black, blue, green, red
4	Ballpoint Pen	Bic cristal		Black, blue, green, red
5	Semi Gel Ballpoint Pen	Panter		Black, blue, green, red
6	Rollerball Pen	Uni-ball Eye UB-157		Black, blue, green, red
7	Ballpoint Pen	Kian crystal		Black, blue, green, red
8	Ballpoint Pen	Canco fino		Black, blue, green, red
9	Rollerball Pen	Sadaf(crystal)		Black, blue, red
10	Rollerball Pen	Sadaf(asman)		Black, blue, red
11	Uncoated paper			-
12	Coated paper			-

Three handwriting pressures including gentle or quiet, medium and strong were applied after a time gap of 1 hour between the printing and writing the ink stroke. The gathered data was a set of both statues, i.e. ink effect on printed text and vice versa. Then, the images of intersection point were captured by a Dino-Lite digital microscope with a 200x magnification in the visible region of the electromagnetic spectrum. The microscope was connected to a color monitor to assess the captured images. Figure 1 shows a schematic illustration of image capturing using a digital microscope. The ten observers with standard color vision tested with the color vision Ishihara test were asked to assess the images to validate the results. The viewing conditions were such that we displayed ten of the images on the monitor one by one and the observer was placed right in front of it.

In order to simplify the evaluations, the different positions of printing and ink in sequence of strokes were abbreviated. Table 2 shows the corresponding symbols.

3. Results and Discussion

As mentioned, digital images-based techniques could be applied to determine the sequence of intersecting lines from print and ink. The parameters related to the printing process, printer, paper, color of ink and ink formulation could be effective to detect the document forgery. In some cases that will be discussed later, while the ink stroke locates on the top, the perceived appearance is accompanied with a specific brightness as well as a highlight reddish-blue effect. It seems when the ink is located on the black toner, the high adsorption of black shade changes the shade of ink specifically. The acquired results of effect of parameters brand, hue, handwriting, printer type and paper type are discussed in details below.

3.1. Effect of brand

The samples in blue hue from 8 brands with medium handwriting pressure were selected to see whether it is recognizable the sequence of printed text with LaserJet printer and ink stroke. As shown in Figure 2, with the exception of one of brands, brightness is perceptible in the intersection of ink stroke and printed text in both status of POI and IOP. In most cases (say 88%), the sequence of ink and print is recognizable except for blue sample of Uniball brand. It can be due to the low viscosity of the ink with more penetration into the paper. Similar results were obtained for other brands.

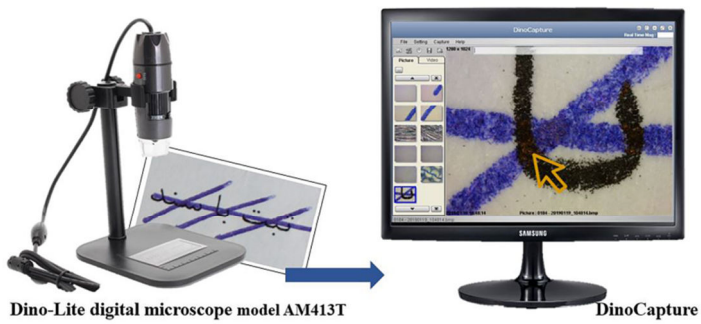

Figure 1: A schematic illustration of capturing and evaluating the images with a digital microscope.

Table2: Symbols used for the status of the abbreviations.

Status	Abbreviations
Print	P
Ink	I
Print On Ink	POI
Ink On Print	IOP

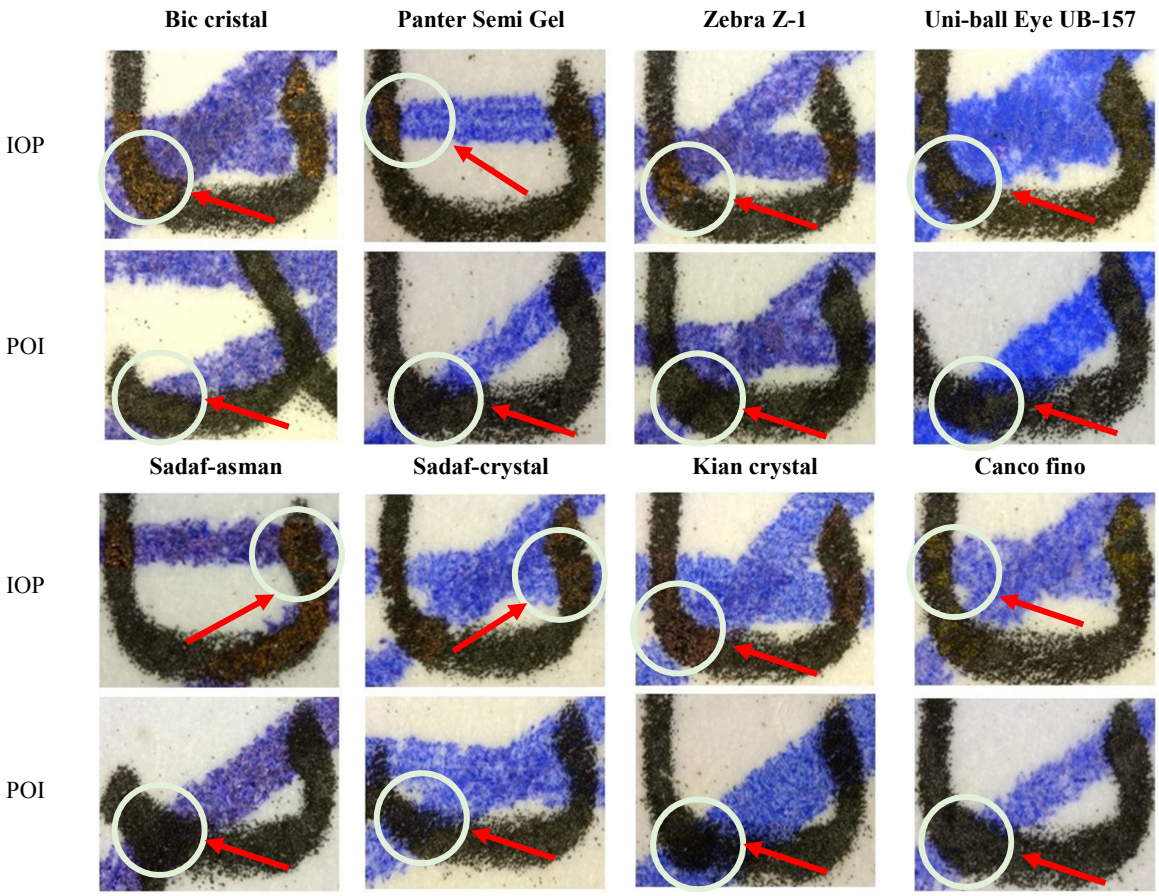

Figure 2: Effect of brand on determining the sequence of intersecting lines.

3.2. Effect of ink hue

Figure 3 shows the results of the hue effect in determining the sequence of strokes for Bic, Uniball and Zebra brand and LaserJet printed text. It is obvious Figure 3 for the black and blue hues, when the ink stroke was over the printed text, the intersection was accompanied by certain brightness as well as a highlight reddish-blue effect. Therefore, with a fairly high degree of precision, it was possible to distinguish the order of ink stroke and printed text in black and blue shades. But it was not recognizable for black and blue hues of Uniball brand. In the green hue, it was not easy to consider this matter because its recognition depends on the type of pen. For example, in Bic, Panter and Uniball, no one can definitely comment on this situation. In the red hue, like black and blue, when the ink stroke was placed on the printed text, there was certain brightness at the intersection that appears to be golden. Among theses 6 brands in which the effect of hues was examined, the sequence of print and ink was recognizable in black hue by 85.7%, in blue hue by 85.7%, in green hue by 28.5% and 100% in red hue.

3.3. Effect of handwriting pressure

As mentioned before, the pen strokes were made in gentle (quiet), medium and strong handwriting pressures by the same person. Figure 4 shows the handwriting pressure effects on determination of the sequence of strokes for LaserJet printed text. The results showed that by increasing the handwriting pressure, the brightness generated by the pen stroke on the toner increases. This intends that at low and average pressures, there is no definitive result in determining the sequence.

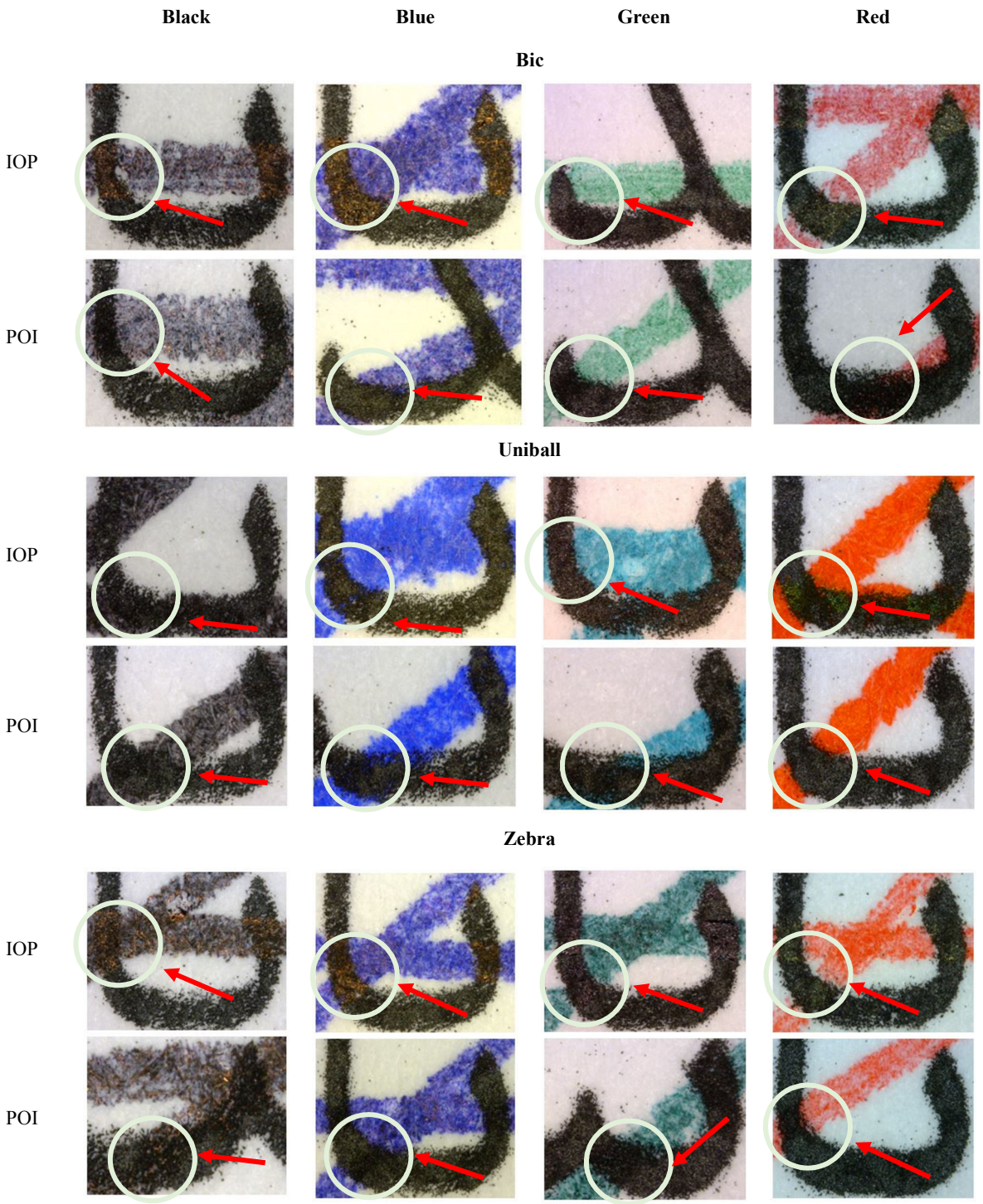

Figure 3: Effect of hue on determining the sequence of intersecting lines.

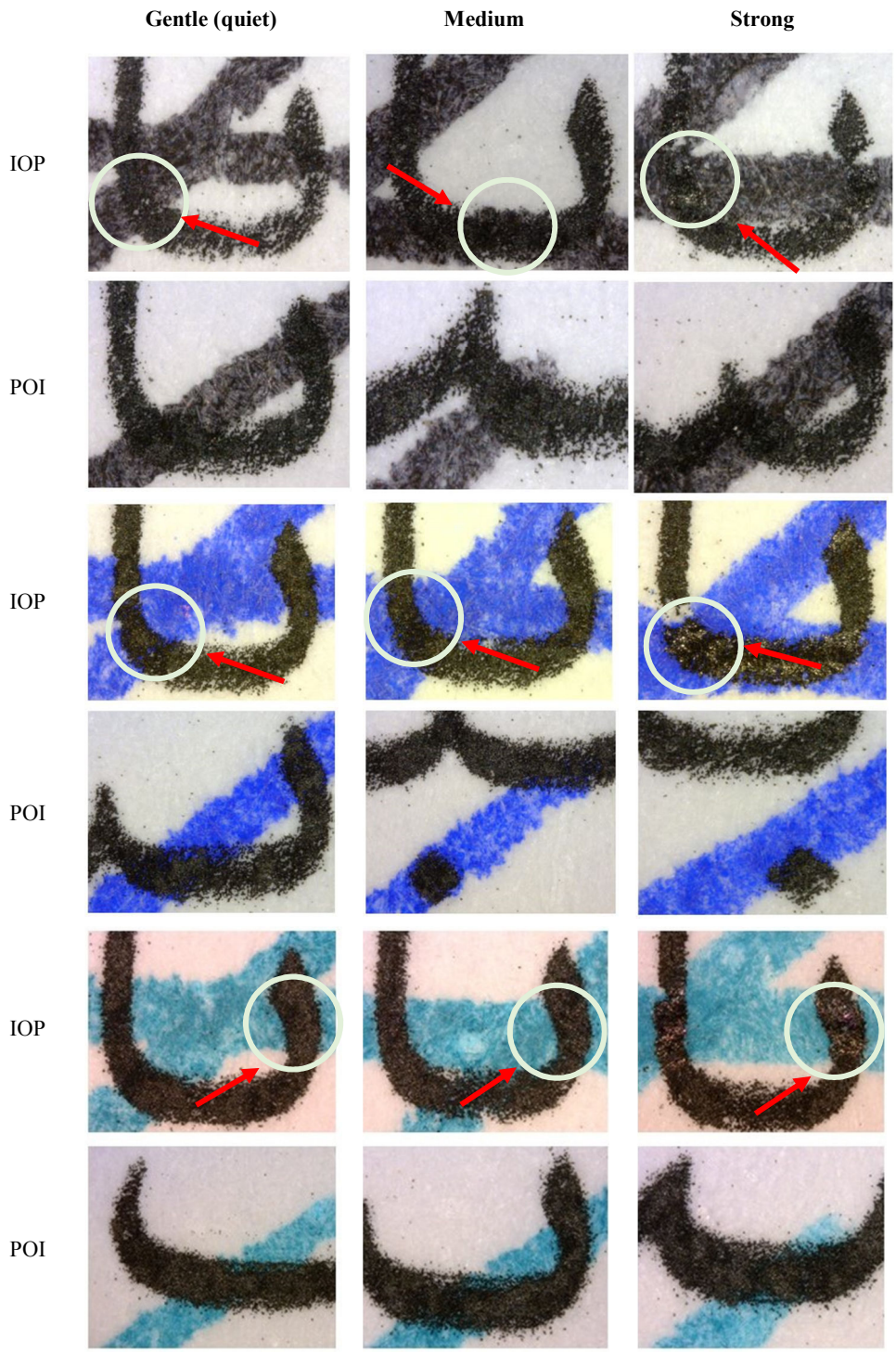

Figure 4: Effect of handwriting pressure on determining the sequence of strokes, Uniball brand and Laserjet printed text.

Figure 4: Continue.

Moreover, the handwriting pressure study has also shown, increasing the handwriting pressure will increase the brightness, except the black hue of Uniball brand. This sample shown no brightness in any handwriting pressure.

3.4. Effect of paper type

The investigations showed that in the printing process, paper and its characteristics have a major role in the final perceived color and the quality of printed image [33]. In the study of the effect of paper type, coated paper and white sheet with fluorescent effect were investigated. Figure 5 shows the intersection of printed text of LaserJet printer and ink stroke. The coated paper surface is smooth and shiny and absorbs ink monotonic. On coated paper, because of the smooth and glossy surface of the tissue and the lack of absorption and traction into the tissues, the ink to remain on the paper surface. Therefore, the observed brightness is greater.

3.5. Effect of printer type

The printing mechanism in Inkjet and LaserJet (toner) printers is quite different and each printer has a unique fashion of printing. Unlike Laser printers, it is observed that the printing mechanism of image in Inkjet printers, ink has a significant penetration into the paper substrate [34]. Accordingly, it was necessary to study the effect of printer type to distinguish and identify the sequence of intersecting lines on printed text and ink for the purpose of forensic examination. Figure 6 shows the intersecting lines prepared for blue Zebra ink from the Canon Inkjet and HP Inkjet for both statutes IOP and POI. One thing that emerges from these figures is the reddish color perception acquired of laser printer in intersecting lines of ink over print (IOP). This may be attributed to the different drying mechanisms of the two printers. In the Laser printer, drying occurs through the toner fusion, in which it is no possible for the ink to penetrate sufficiently and the redness will be perceived by the ink remaining on the toner. On the other hand, in inkjet printer, the drying occurs through penetration so that the ink penetrates into the paper and the drying is performed by evacuating the solvent. Moreover, considering the variation for Inkjet printer showed no significant difference between both statutes IOP and POI. Undetectable difference similar to that obtained by inkjet printer was found for other hues and brands.

Table 3 presents a brief review of the results obtained in this study. It should be noticed that to get certain results for each section and parameters, more details studies are needed. The recognition of the sequence of print and ink strokes is a challenging and needs more experience with complete data analysis.

Table 3: Ability to recognition of sequence of print and ink strokes according to the effective parameters.

Effect of brand	All brands except blue of Uniball
Effect of ink hue	Red:100% Blue, Black: 85.7% Green: 28.5%
Effect of handwriting pressure	increasing the handwriting pressure
Effect of paper type	Coated paper
Effect of printer type	LaserJet printer

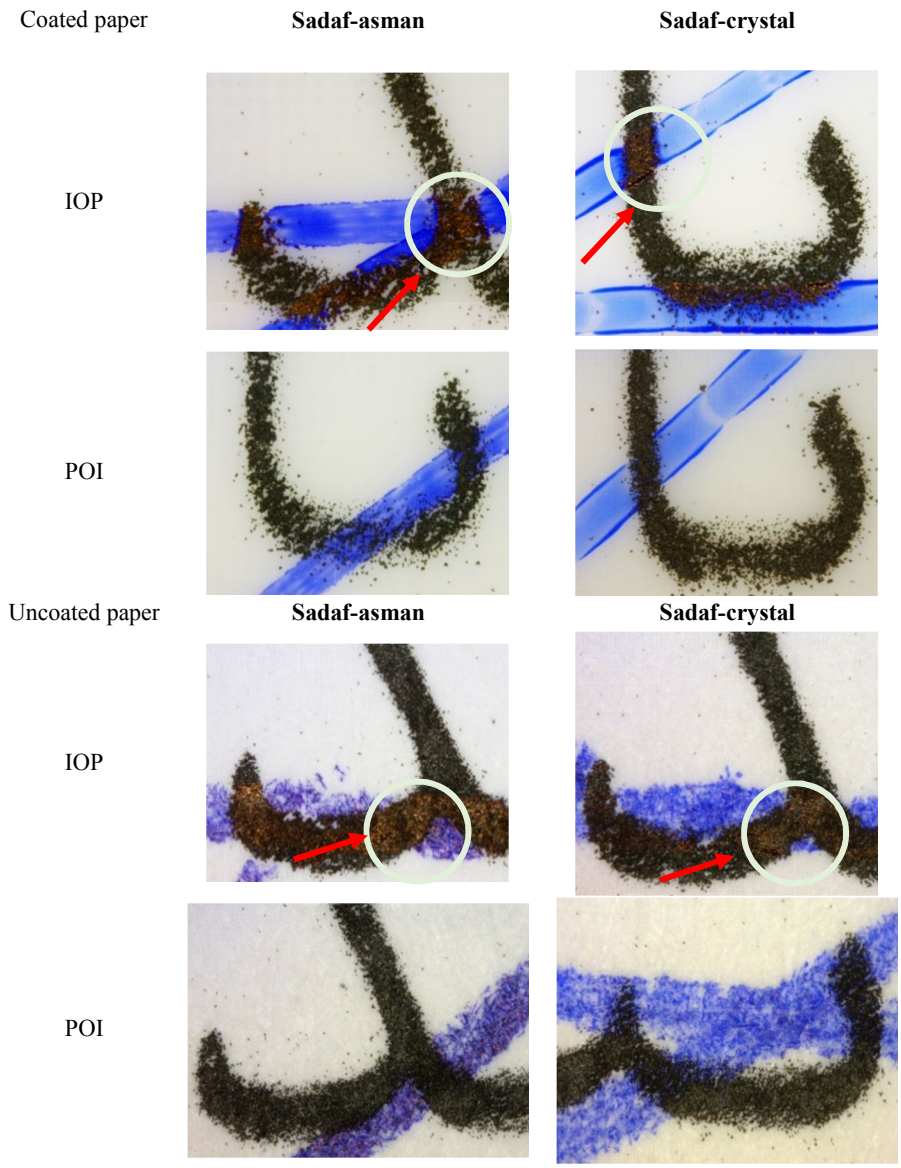

Figure 5: Effect of paper type on determining the sequence of strokes.

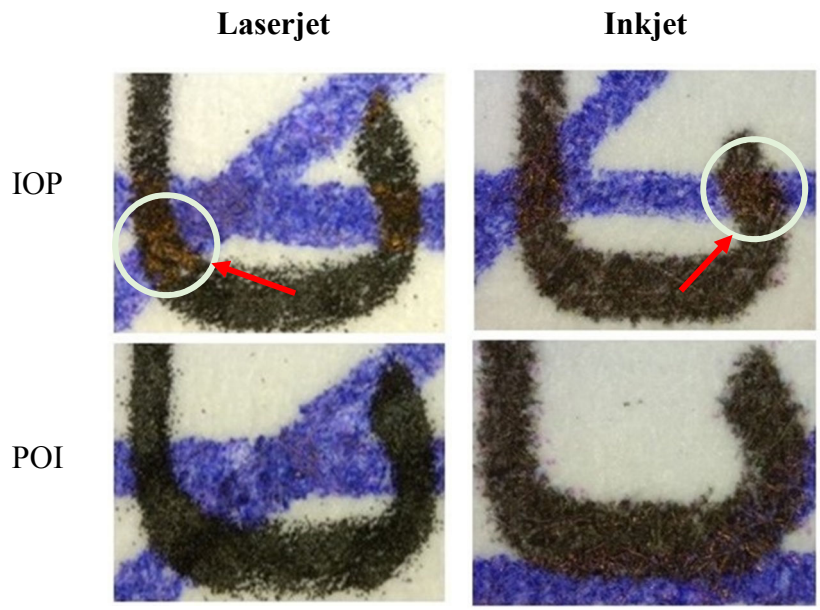

Figure 6: Intersecting lines for blue Zebra ink from Canon Inkjet (Right) and HP Laserjet (Left); Top: IOP sample; bottom: POI samples.

4. Conclusions

In this work, the sequence of commercial black, blue, green and red pens (inks) and a printed text was subjectively considered at the point of intersection. Observations showed that the use of a digital microscope is not appropriate for any of the intersections of the ink and inkjet stokes. Although in cases where the LaserJet printer was used, the existence of ink stroke on the toner of LaserJet printer is accompanied with a sensible brightness. In the blue, black and red hues, the sequence of toner and ink stroke can be recognized in most cases, but the recognition is difficult (or impossible) in green hue. The effect of printing parameters (hue of ink, brands of inks, handwriting pressure, type of printer and types of paper) was investigated using Dino-lite digital microscope. By comparing these cases, it was seen while the ink stroke was on the top, the appearance of intersection in some cases is accompanied with a specific brightness as well as a highlight reddish-blue effect. In section of brand effect, in the blue hue of 8 used brands, in 88% of the cases, sequence of ink and print is recognizable except for blue of Uniball brand. Among the 6 brands in which the effect of hues was examined, sequence of print and ink is recognizable in the black hue in 85.7%, in the blue hue in 85.7%, in the green hue in 28.5% and in the red hue in 100% of brands. In general, it was shown that by increasing the handwriting pressure, the brightness increases, except the black hue of Uniball brand. No brightness was observed in any handwriting pressure for the black hue of Uniball brand. The reason for the acquired brightness at the point of intersection is not still clear to the authors.

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How to cite this article:
A. Tajik Esmaeili, M. Ataeefard, M. Safi, Recognition of Sequence of Print and Ink Strokes: Investigation the Effect of Handwriting Pressure, Hue of Ink, Printer and Paper Type. Prog. Color Colorants Coat., 12 (2019), 251-261.