Application Note

Imaging of Inks on Questioned Documents Using Fluorescence and Visible/Near-Infrared Reflectance Hyperspectral Imaging

Introduction

Traditionally, questioned document examiners have utilized visible to near-infrared (NIR) reflectance/absorbance, fluorescence imaging, optical microscopy and photography as tools to identify, capture and characterize questioned documents. ChemImage hyperspectral imaging (HSI) technology was developed to extend these traditional capabilities, improving visualization and providing additional information about a sample's formulation. HSI combines standard digital imaging techniques with common spectroscopic methods to provide increased sensitivity and discrimination capabilities over traditional methods of questioned document analysis. A validated and accepted technique, HSI is becoming a commonly utilized technology for questioned document analysis. The analysis is nondestructive and requires little or no sample preparation, therefore decreasing the chances of possible contamination.

The advantage of HSI lies in the information embedded within the image. Because the images are a series of snapshots collected as a function of wavelength, each pixel within the image has a fully resolved spectrum associated with it. This method of data collection allows for better visualization and discrimination of a wider range of documents. In addition, the type of information contained in hyperspectral images is easier to interpret for non-scientists, making the presentation of data and information to jurors in the courtroom easy and straightforward.

Experimental Information

A hyperspectral image is generated by collecting digital images as a function of wavelength through the use of an electro-optic tunable imaging filter.

Images can be collected through the visible to NIR range (400-1100 nm) in reflectance mode (broadband white light illumination) or through the visible range (400-720 nm) in fluorescence mode (300-400 nm UV excitation). Following data acquisition, ChemImage image processing software may be used to generate univariate (i.e., single wavelength) images characteristic of absorbance, reflectance or fluorescence exhibited by inks of interest. Alternatively, through the use of multivariate (i.e., multiple wavelengths) statistical tools, the software draws from the variability present at a range of wavelengths to enhance image contrast and reveal minor differences between different inks. Conventional imaging-based document analysis systems that solely rely on single wavelength images are not capable of this superior level of image enhancement.

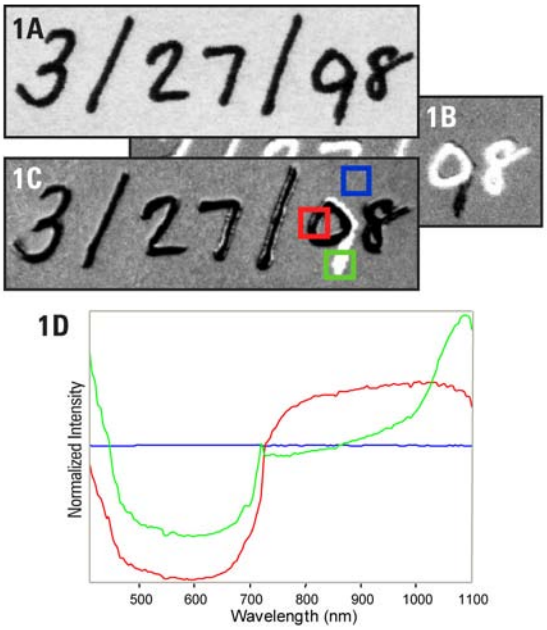

Figure 1. *Altered date on a contract. 1A shows the optical image of the sample. 1B shows a 440 nm visible reflectance hyperspectral image extract. 1C shows an 865 nm near-infrared reflectance hyperspectral image extract.*

Results & Discussion

ChemImage HSI differs from the conventional

method of document examination in that it utilizes a liquid crystal tunable filter (LCTF) in place of a general barrier filter/camera configuration. The LCTF is a computer controlled, electro-optic device that can be tuned to transmit any discreet wavelength across the visible or NIR region of the spectrum (i.e., 400-1100 nm). Because different brands and types of inks have varying formulations, the absorbance, reflectance or luminescence properties of the inks will differ.

Ink/questioned document analysis with ChemImage hyperspectral imaging technology employs visible to NIR reflectance as well as fluorescence modes. Contrast within the image is generated from the varying reflectance or emission that the ink exhibits at a particular wavelength. The pixel intensities of the image are plotted as a function of wavelength and therefore produce the reflectance or fluorescence spectrum associated with the sample.

Figure 1 shows information from a hyperspectral image revealing the alteration in the year portion of the date, by showing contrast in the visible and NIR image extracts. The contrast exhibited in the images between the different inks and the paper substrate is a result of the inherently dissimilar reflectance properties (and therefore dissimilar formulations) of these materials. The optical image of the sample is shown in Figure 1A. Figure 1B shows a 440 nm visible reflectance hyperspectral image extract while image 1C shows an 865 nm near-infrared reflectance hyperspectral image extract. The underlying spectral differences in the two inks and the paper background can be seen in image 1D.

Figure 2 shows information from a hyperspectral image of a forged check. Figure 2A shows a digital image and corresponding fluorescence hyperspectral image resulting from two different inks used to generate the number "4" on the check. The horizontal line in the "4" was written using one type of blue ink while the vertical line was drawn using a second type of blue ink. The spectra are shown in Figure 2B. Image pixels correlating with the fluorescence inherent to the ink used to draw the horizontal and vertical lines were colored blue and green, respectively. The "black" pixels in the image show portions of the image that did not correlate with the spectral properties of the inks. These image regions are associated with the paper substrate.

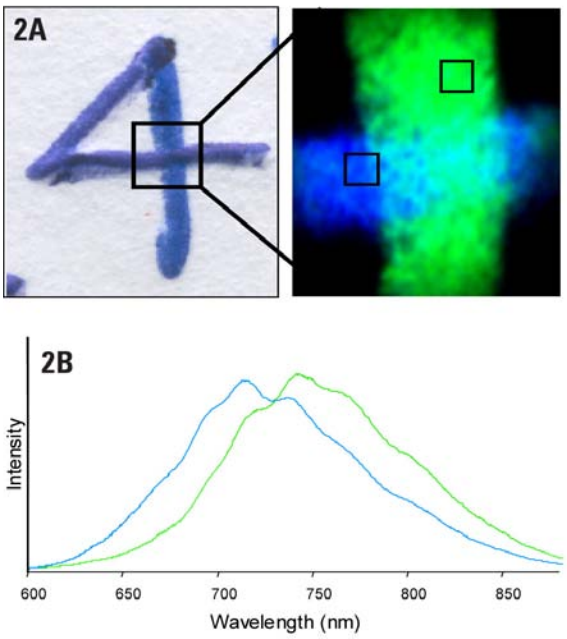

Figure 2. *Altered number on check. 2A shows a digital image and corresponding fluorescence hyperspectral image resulting from two different inks used to generate the number "4". 2B shows the corresponding spectra*

(Work performed in collaboration with the Australian Federal Police)*

Conclusion

- More information is obtained though HSI than though traditional methods of analysis
- HSI enables examiners to analyze a wider range of evidence
- HSI provides accurate, reliable, validated, courtroom friendly results
- Data can be obtained in a nondestructive manner

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ANREV003
06/2011