MICRO-RAMAN MAPPING of DISSIMILAR INKS on PAPER

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Introduction

When documents are altered the order of ink layer deposition where lines cross is an important determinant in forensic examinations. Knowledge of the top layer suggests the intent of the alteration while the lower layer provides information about the document’s original content. Together, this information helps establish motive and may suggest a suspect or timeline of the crime.

Materials and Methods

Instrument Settings

In general, a top-to-bottom approach is required to determine the optimal compromise between spatial resolution and signal strength. Raman excitation was 785 nm, 30 second exposure time, 10% laser power and two accumulations. Spectral response was measured from 3200 cm⁻¹ to 850 cm⁻¹. Different magnification and confocality settings were needed for each step.

Step 1. Reference spectra were determined at low confocality and 20x magnification. Step 2 and Step 4. 5x magnification was needed to produce 20 micrometer  x 20 micrometer pixel dimensions for mapping. Data was acquired at low confocality to maximize signal strength and overcome minor out-of-focus conditions caused by paper surface undulations.

Step 5. Depth mapping was performed using 50x at high confocality. Additional acquisitions were required to compensate for low signal strength.

Spectral Matching

Identifying different inks and mapping their locations relied on matching the spectra of unknown inks in the questioned area to known reference spectra of the inks in the body of the document. Direct Classical Least Squares (DCLS) fitting of the unknown data to a linear combination of the known ink reference spectra was conducted using the “Component Analysis” feature in WiRE 3.4 software (1).

Step 1.

Identify Inks in the Document

Reference Spectra

Conversion of spectra into false colors was achieved by making a false color overlay of the reference spectra of the inks in the body of the document. Each pixel contains a color that indicates the ink present at that location.

Results

Step 1.

Identify Inks in the Document Infrared

Reference Spectra

Spectra and False Color Assignment

Figure 1. Reference Spectra for Ink A (red) and Ink B (green).

Figure 2. Analyzing Each Pixel Location to Determine Photographic and Infrared Spectral Information.

Step 2.

Data Acquisition from the Questioned Area

False Color Shows Locations of Individual Inks

Digital photographs are a collection of pixels arranged in a grid pattern in which each pixel contains a color that is analogous to a photographic image. Each pixel in a scan contains photographic data plus the infrared spectrum at that location. To determine which ink was present, the spectrum at each pixel location was compared to the ink reference spectra using DCLS component comparison in WiRE 3.4 software (1).

Step 3.

Constructing a Map of Ink Locations

Each Pixel Contains

Photographic Information

Infrared Spectrum (only one)

Figure 3. Compiling the Infrared Spectral Information in Each Pixel to Create a False Color Map Showing the Location of Inks A and B

Step 4.

Top Ink Determination at the Point of Line Crossing

In circumstances where the sequence of deposition is not evident from the context of the document, additional analysis is necessary to determine the sequence of application. Both surface and depth mapping techniques provide this information in different ways.

Surface Mapping Technique

In Figure 5, the grid at the light colored box defines the mapped area; cells in the grid are pixels. Pixel area was set by the motorized stage “Step” setting that adjusts the distance traveled between data acquisition points. Greater detail can be achieved with smaller steps and higher magnification of the expense of reduced signal strength. Trial-and-error was needed to determine the optimal balance of these settings.

Depth Mapping Technique

In Figure 6, the depth map indicating the sequence of line deposition in panel A above the intensity of both ink spectra are plotted against distance above the paper surface. The individual pixels for the top and underlying layers in panels B and C respectively. The intros were identified by their spectra using the “Component DCLS” function to identify the best fit of the pre-inked spectrum to the ink reference spectra.

Discussion

Although technical details are critical to the examiner, it is important to communicate the results in a manner that is comprehensible to the juror. This work illustrates a visual presentation based on instrumental analysis that requires little technical knowledge to be understood by a lay audience.

References

WiRE 3.4 spectrometer software is a produce of Renishaw plc, Spectroscopy Products Division, Old Town, Wotton-under-Edge, Gloucestershire, GL12 7DW, United Kingdom.

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