A Review of the Spectrometer and Chromaticity Capabilities of the VSC 2000

Tobin Tanaka

Solicitor General Canada, P.O. Box 9732, Station "T," Ottawa, Ontario K1G 4G4 CANADA

Differences between inks are often observed by Forensic Document Examiners (FDEs) through the use of infrared (IR) reflectance. Such differences are observable in real time with CCD cameras and appropriate filters on such coupled instruments offered by Projectina and Foster + Freeman. These differences in IR reflectance are usually observed and distinguished through qualitative analysis. Until recently, quantitative analysis could be accomplished but would require extensive manual collection of data, subsequent statistical processing, and plotting of data points. The VSC 2000 offers an automated system which yields quantitative data useful in the discrimination of inks. A brief explanation of the utility and limitations encountered will be discussed.

Introduction

When an incident IR light source is used for the illumination of a document bearing inks, bandpass filters with an IR sensitive camera allow for the separation of different inks. This separation of inks is often visible and qualitatively observed. Part of the reason that only a qualitative observation is made may be due to the inconvenience of having to collect together grayscale data for numerous bandpass filter settings, and then having to extract the spectral data. The advantage of spectral data is that several inks can be separated via IR reflectance and shown in one picture, whereas several pictures would have to be used to demonstrate why the inks are different by conventional means.

The VSC 2000 has four options in the spectrometry feature built into the instrument: reflectance, absorption, transmittance, and fluorescence. Only the absorption spectrometry features will be discussed in this paper, although reflectance and absorption are related.

The views expressed in this paper are those of the author and any mention of trade or commercial names does not constitute endorsment by the Solicitor General of Canada or the Government of Canada.

Methods and Materials

All comparisons are made with respect to a "standard white tile" which is an object which theoretically reflects all of the incident radiation in the bandwidth concerned, in this instance from 400 nm to 1000 nm. The comparison is made between an area of ink on a document and an area on the "standard white tile." The black and white CCD camera on the VSC 2000 has 256 gray levels of intensity, 0 is jet black, 255 is saturated white. Two separate matrices of pixels are selected from the VSC image, one matrix of pixels is centered on the ink sample, the other matrix is centered on the "standard white tile." During the operation of the data collection, the matrix centered on the ink sample is outlined in blue on the monitor, and the matrix centered on the "standard white tile" is outlined in red on the monitor. Once the focus is adjusted and verified by the operator, the following steps automatically take place (see also Appendix A):

1. The bandpass filter (nominal width 42 nm) moves to the first position 400 nm, and the light source automatically reaches full intensity.

2. Each pixel within both the blue matrix and red matrix will have a grayscale value between 0 and 255. There should not be that much variance in grayscale value from pixel to pixel in the blue box or red box.

3. Add the grayscale values together for each pixel in the blue matrix, the ink sample.

4. Add the grayscale values together for each pixel in the red matrix, the "standard white tile."

5. Divide the total of step 3 by the size of the matrix of pixels (either 64, 36, 16, or 4), the total number of pixels in the matrix, that yields the average grayscale value for the blue matrix, the ink sample. Hereafter referred to as B_{ave}.

6. Divide the total of step 4 by the size of the matrix of pixels (either 64, 36, 16, or 4), the total number of pixels in the ma trix, that yields the average grayscale value for the red matrix, the ink sample. Hereafter referred to as R_{ave}.

7. Calculate an intensity value as a percentage, for absorption: (B_{ave}/R_{ave}) 100 = I. If the ink sample is as reflective as the "standard white tile" the intensity value is 100%.

8. Repeat Step 1, the bandpass filter is moved to the next position 403 nm. I_{493} is then calculated.

9. Repeat the steps above so that each $I_?$ from I_{400} to I_{1000} is calculated and then plotted as intensity ($I_?$) vs. wavelength ? (center of the bandpass filter). In total, 180 data points for each dataset are collected. It should be noted that the iris is adjusted by the instrument as needed to reduce the presence of "noise" in the image.

Practical Tests and Preparation of Test Sheets

Some practical tests were conducted to determine the utility of the VSC 2000 spectrometer:

- Does the same spectral curve appear for the same ink line when run multiple times?
- When does the spectral data give the document examiner an advantage over a qualitative separation of inks?

Several test sheets were prepared on Rolland Inc., letter size Repro 50% recycled, 75 g/m^2, white paper. All test sheets originated from the same sealed package, and each test sheet was produced by the same writer. Preparation was conducted by placing the test sheet onto a desk blotter composed of paper. This resulted in a slightly elastic writing surface. Since all the pens were new or almost new, all of them were "jump started" by writing a short line on a scrap of paper to ensure proper ink flow before writing onto the test sheet. The following test sheets included: blue ballpoint/gel writer, black ballpoint, and red ballpoint writing instruments.

Data and Observations

The "standard white tile" that was supplied with the instrument was not used, instead a Kodak White Reflectance Standard (chemical #6091) was used. The reason for this change was due to the high reflectance properties that this standard exhibited through the entire bandwidth from 400 nm to 1000 nm. Each ink line from all test sheets was measured 5 times and these data were averaged so that one data set per pen resulted (Table 1). Random parts of the ink line were selected, however, initial and terminal parts of the ink lines were avoided to ensure that an adequately linked source was examined.

Results

An examination of the data resulting from the tests indicate that the samples of each data set tended to demonstrate repeatability. In other words, a similar spectral curve resulted for each sample taken from an ink line. By visual examination only, it was evident that the sample curves were clustered together in the visible range of the data from about 500 nm to 800 nm. At the 400 nm to 500 nm range there is a greater "spread" in the data. This may be due to the lower sensitivity of the CCD camera at that range. A similar type of observation is observed between 800 nm and 1000 nm. As noted above, all of the ink lines were written on the same type of paper. It may prove to be useful in a future study to write with the same pen on several different types of paper to determine how the spectral data changes. Examination of the spectral plots revealed where the differences between inks were located, right down to a few nanometers.

TYPE	DATA SET
Blue Ballpoint and Gel Writer Pens:	
Bic PM-39 Medium Point	01
Bic L-G-31 Clear Barrel	02
Bic Softfeel Fine	03
Bic Q-G-17 Blue Barrel	04
Papermate Flexgrip Ultra	05
Papermate Flexgrip	06
Papermate Medium Powerpoint	07
Erasermate 2 Medium	08
Pilot BP-S Medium	09
Pilot Better Retractable Fine	10
Parker Ball Pen Refill Fine	11
Roundedge Grand & Toy Medium 99051	12
Staedtler Stick 430M	13
Roundedge Grand & Toy 99204	14
Sanford Uni-gel Medium	15
Pentel R.S.V.P. Fine	16
Black Ballpoint Pens:	
Bic PM-39 Medium Point	17
Bic M-G-10 Clear Barrel	18
Papermate Medium Point Black Barrel	19
Erasermate 2 Medium	20
Pilot BP-S Fine	21
Pilot Better Retractable Fine	22
Parker Ball Pen Refill Medium	23
Roundedge Grand & Toy Fine 99205	24
Staedtler Stick 430M	25
Sanford ZeZe Medium	26
Pentel Office Ball BK13	27
Red Ballpoint Pens:	
Bic PM-39 Medium Point	28
Bic M-G-16 Clear Barrel	29
Erasermate 2 Medium	30
Pilot BP-S Fine	31
Roundedge Grand & Toy Fine 99213	32
Pentel Superb BK 77	33

Table 1. Ballpoint and Gel Writer Pens

Discussion

The spectrometer feature of the VSC 2000 is useful, but there are limitations. Differences in the environment, such as the age of the IR light source, the type of paper used for writing, and the variation between the "standard white tile" will influence the data. For these reasons, it is probably not possible to construct an ink library of spectral data for identifying which type of pen(s) were used on any document.

To emphasize again, the spectrometer when used for *comparative* purposes can be of value. When the data from several different inks are plotted together, it is easier to demonstrate the differences between several inks.

Chromaticity Diagram

Related to the spectrometer data is the Commission Internationale de l'Eclairage (CIE) Chromaticity Diagram. This diagram is designed to represent the perception of color by the human eye when an object is illuminated by certain light sources. Guidelines established by the CIE suggest that an object's color be measured by an equal energy light source. Strictly speaking, no such light source exists in nature or synthetically. In practical terms, though, there are several accepted CIE illumination sources which are used for scientific use.

- Equal Energy (as close to the ideal equal energy light source mentioned above)
- Illuminant A – gas filled lamp – correlated color temperature of T=2854 K (Red)
- Illuminant B – filtered sunlight – correlated color temperature of T=4870 K (Green)
- Illuminant C – approximate daylight (sun & sky) correlated color temperature of T=6670 K (Blue)
- Illuminant D_{65} – color temperature 6500K

Naturally, the illuminant used to illuminate an object will change the color that is observed by the eye or anything used to detect color. This change in color perception explains why photographic film is color balanced, usually for "daylight" photography, but there is also "tungsten" balanced film. The VSC default is for the Equal Energy setting. The user can select a different illuminant, and the chromaticity data is then interpolated to match the new illumination source.

Appendix A

b_{IJ} = grey scale value blue box pixel element (ink sample)

r_{ij} = grey scale value red box pixel element (standard white tile)

Where I,j represent the row and column respectively of that pixel element within the matrix. Both I and j are between 1 and n, where n is the size of the matrix of pixels.

$0 = b_{ij}, r_{ij} = 255$

Each pixel within the blue and red matrix will have a grayscale value between 0 and 255.

B_{ave} = average gray value of the blue matrix (ink sample), $B_{ave} = S\, b_{ij}/n^2$

R_{ave} = average gray value of the red matrix (standard white tile), $R_{ave_e} = S\, r_{ij}/n^2$

The Intensity (I) expressed as a percentage is then:

$I = 100\ (B_{ave} / R_{ave_e})$

Note R_{ave} ? 0

Center wavelengths in nm of bandpass filter, a total of 180 data points for each data set:

400, 403, 407, 410, 413, 417, 420, 423, 427, 430, 434, 437, 440, 444, 447, 450, 454, 457, 460, 464, 467, 470, 474, 477, 480, 484, 487, 490, 494, 497

501, 504, 507, 511, 514, 517, 521, 524, 527, 531, 534, 537, 541, 544, 547, 551, 554, 558, 561, 564, 568, 571, 574, 578, 581, 584, 588, 591, 594, 598

601, 604, 608, 611, 615, 618, 621, 625, 628, 631, 635, 638, 641, 645, 648, 651, 655, 658, 661, 665, 668, 672, 675, 678, 682, 685, 688, 692, 695, 698

702, 705, 708, 712, 715, 718, 722, 725, 728, 732, 735, 739, 742, 745, 749, 752, 755, 759, 762, 765, 769, 772, 775, 779, 782, 785, 789, 792, 796, 799

802, 806, 809, 812, 816, 819, 822, 826, 829, 832, 836, 839, 842, 846, 849, 853, 856, 859, 863, 866, 869, 873, 876, 879, 883, 886, 889, 893, 896, 899

903, 906, 909, 913, 916, 920, 923, 926, 930, 933, 936, 940, 943, 946, 950, 953, 956, 960, 963, 966, 970, 973, 977, 980, 983, 987, 990, 993, 997, 1000

Examination of the CIE plots from the data sets revealed that the data for inks of a similar color clustered together. Subtle differences between the inks did not appear as apparent as with the spectral data. An explanation of this may be due to the fact that this is a measurement of color, not the entire spectral output. For example, suppose that a pen with “ink q1” has a “color q1.” In theory, it may be possible to blend other inks together (“inks q2 and q3”) which will result in the same color as “color q1.” The color of “ink q1” and “inks q2 and q3” are the same, but the spectral curves may not be exactly the same.

Conclusion

As indicated, the spectrometry features of the VSC are useful in the limited tests that were outlined here. Several more tests would be of benefit with different types of pens and printing inks. Further testing of the CIE chromaticity data should also be conducted to determine how this data could be utilized to the fullest extent.

References

Foster + Freeman (1997). *VSC 2000 Installation and instruction manual for software version 2.0.*

Tobin, D., and Wagner, P. (1998). Private communication.