

An Evaluation of Gray Value Measurements and Hyperspectral Imaging as a Method For Analyzing Optical Characteristics of Porous-Tipped Pen Inks

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INTRODUCTION

Porous-tipped pens were first introduced in the mid-1900s and have since evolved into a popular, widespread writing instrument. They not only have traditional, non-artistic purposes such as writing, highlighting, and marking. Porous-tipped pens can also be used for artistic applications to create blended ink creations. These blended pieces can offer some difficulty to a forensic document examiner in terms of analysis, as the blending process makes it a challenge to distinguish between ink colors based on visual analysis alone.

While filtered light examination is a commonly used and effective method of analyzing pen inks, it can be subjective. Both gray value analysis and hyperspectral imaging have been previously used in various fields ranging from biomedicine to security to forensic science, however the applications of these methods to porous-tipped pen analysis remains relatively unexplored. In this project, artistic and non-artistic porous-tipped pens from several brands were used to create single ink stroke and blended ink samples.

It is hypothesized that gray value analysis and HSI can be used to obtain numerical data in order to more objectively differentiate between porous-tipped pens and to link known porous-tipped pens to unknown inks in a blended sample. The goal of this project is to determine the most efficient protocol to objectively characterize and differentiate blended porous-tipped pen inks based on their optical characteristics.

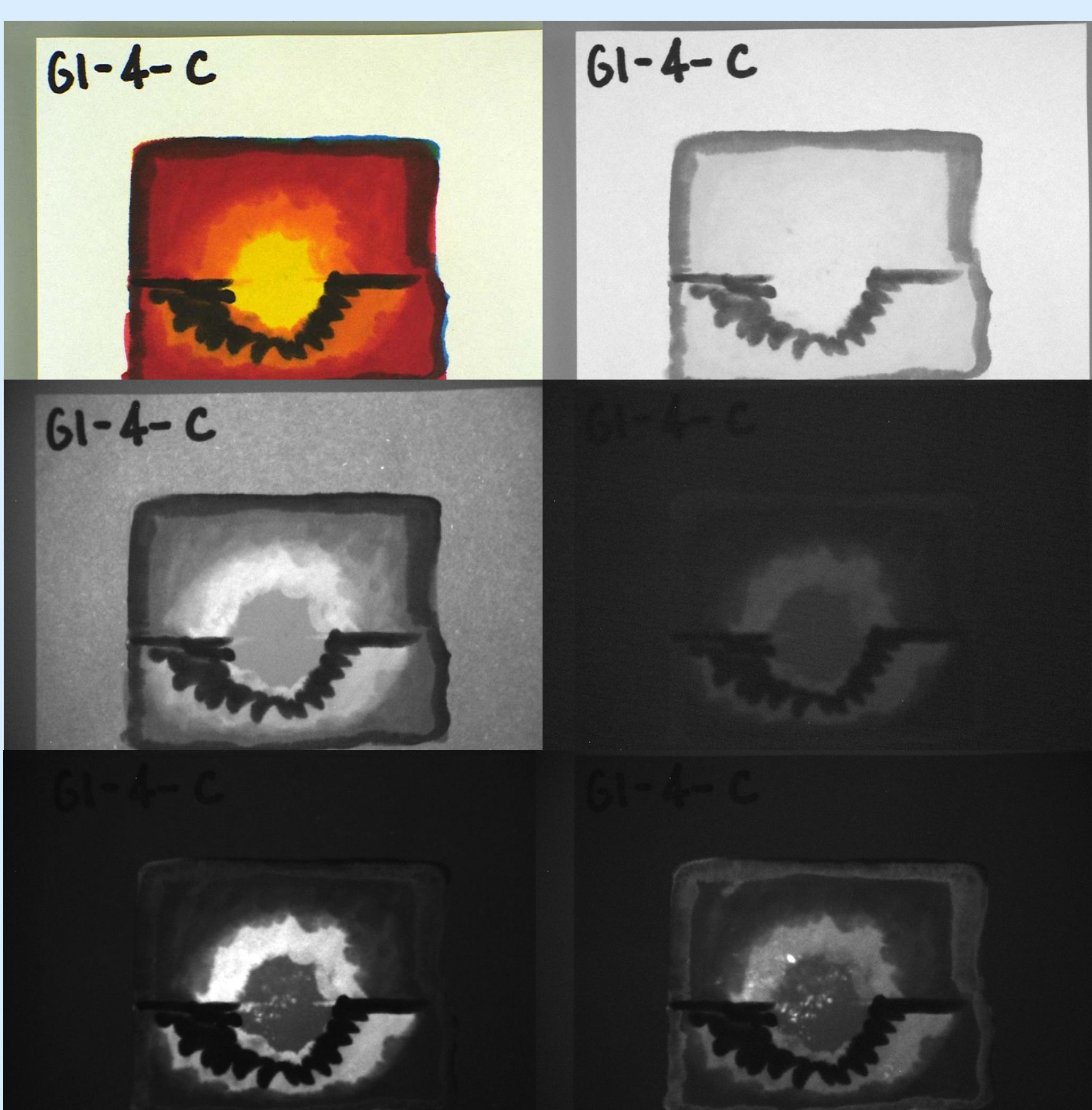


Figure 1: Blended ink sample made with randomly chosen marker inks captured under different light filters to show optical characteristics such as infrared (IR) reflectance and IR luminescence.

MATERIALS & METHODS

Samples – single ink stroke samples and blended ink sample:

- Black, red, red, orange, yellow, green, and blue colors chosen from 5 artistic marker brands and 6 non-artistic* marker brands.
- Marker brands: Arteza®, Copic®, Prismacolor®, Spectrum noir™, Tanmit, amazonbasics*, Paper Mate®, Pentel®, Sharpie®, Staples®, and universal®*.
- Four different artistic paper mediums.

Comparisons:

- Ink stroke samples: artistic vs artistic, artistic vs non-artistic.
- Artistic ink stroke samples vs blended ink sample.

Visual comparisons

Filtered light examination using VSC

HSI using VSC

Gray value analysis using ImageJ

Data analysis: PCA and One-Way ANOVA

Hyperspectral Imaging

Artistic vs Artistic: 88 ink strokes differentiated

Artistic vs Non-artistic: 61 artistic ink strokes differentiated, 47 non-artistic ink strokes differentiated

- Visual analysis of the reflectance spectra confirms that paper has an influence on recorded spectra.
- PCA plots show complete distinction in 4 black samples, 5 blue samples, and 1 yellow sample.

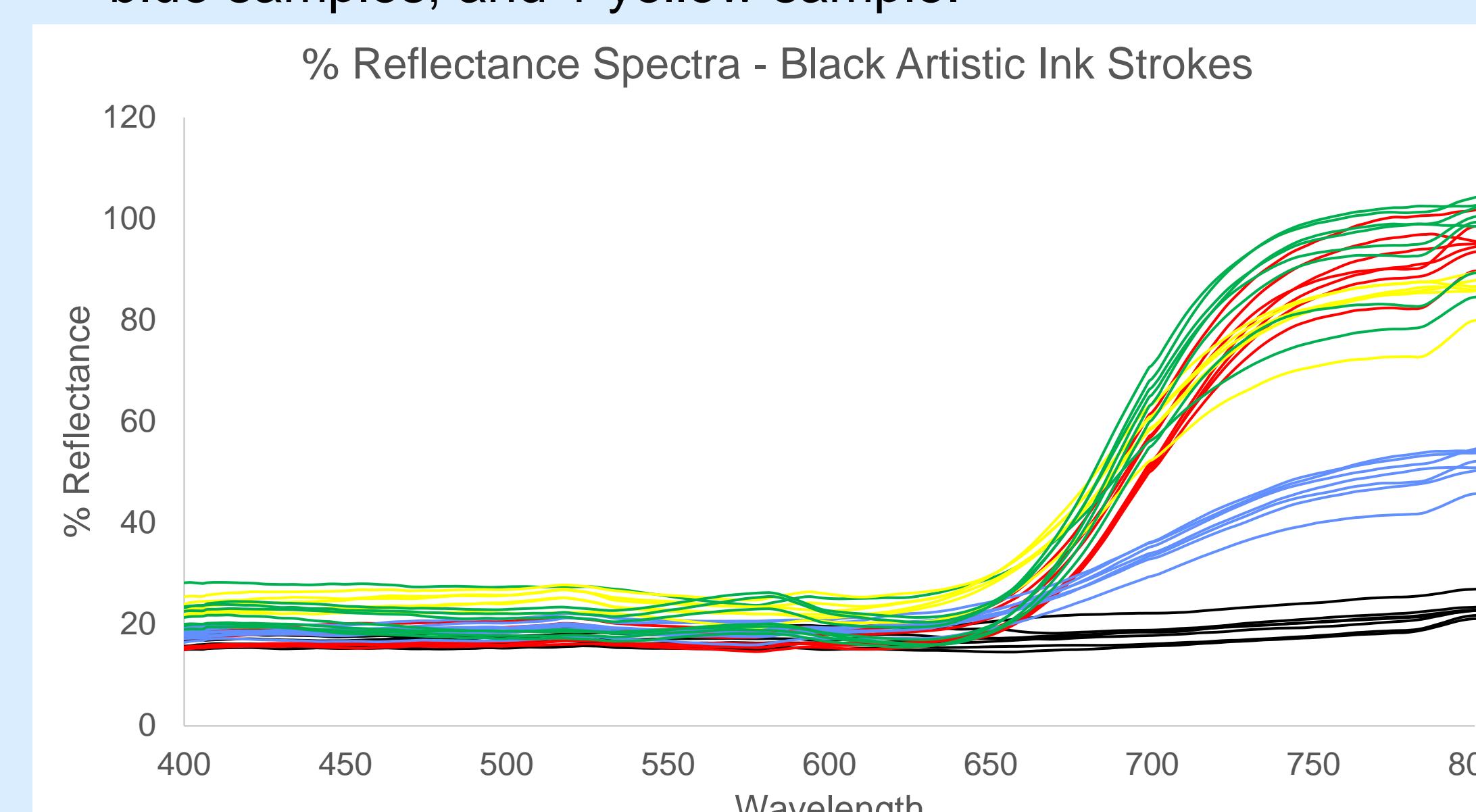


Figure 3: Reflectance spectra comparing the data cubes of 5 black artistic ink strokes on the Canson® Fanboy™ paper medium.

RESULTS & DISCUSSION

Visual Examination

Artistic vs Artistic: 48 ink strokes differentiated

Artistic vs Non-artistic: 40 artistic ink strokes differentiated, 34 non-artistic ink strokes differentiated

Filtered light Examination

Artistic vs Artistic: 105 ink strokes differentiated

Artistic vs Non-artistic: 117 artistic ink strokes differentiated, 92 non-artistic ink strokes differentiated

- Artistic blacks, blues, and yellows and the non-artistic reds were most difficult to differentiate visually.
- Non-artistic ink stroke samples showed fewer optical characteristics compared with artistic ink stroke samples.

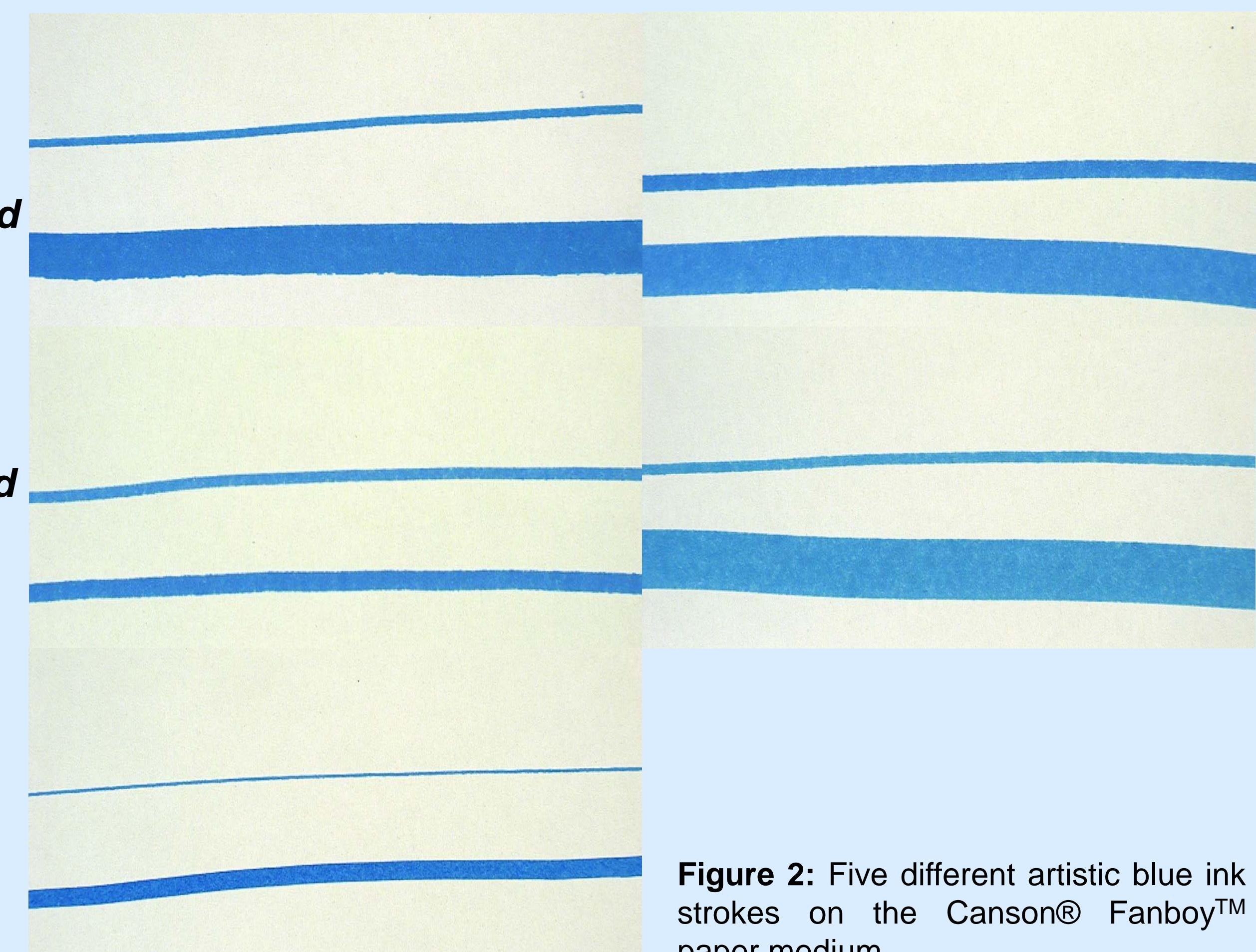


Figure 2: Five different artistic blue ink strokes on the Canson® Fanboy™ paper medium.

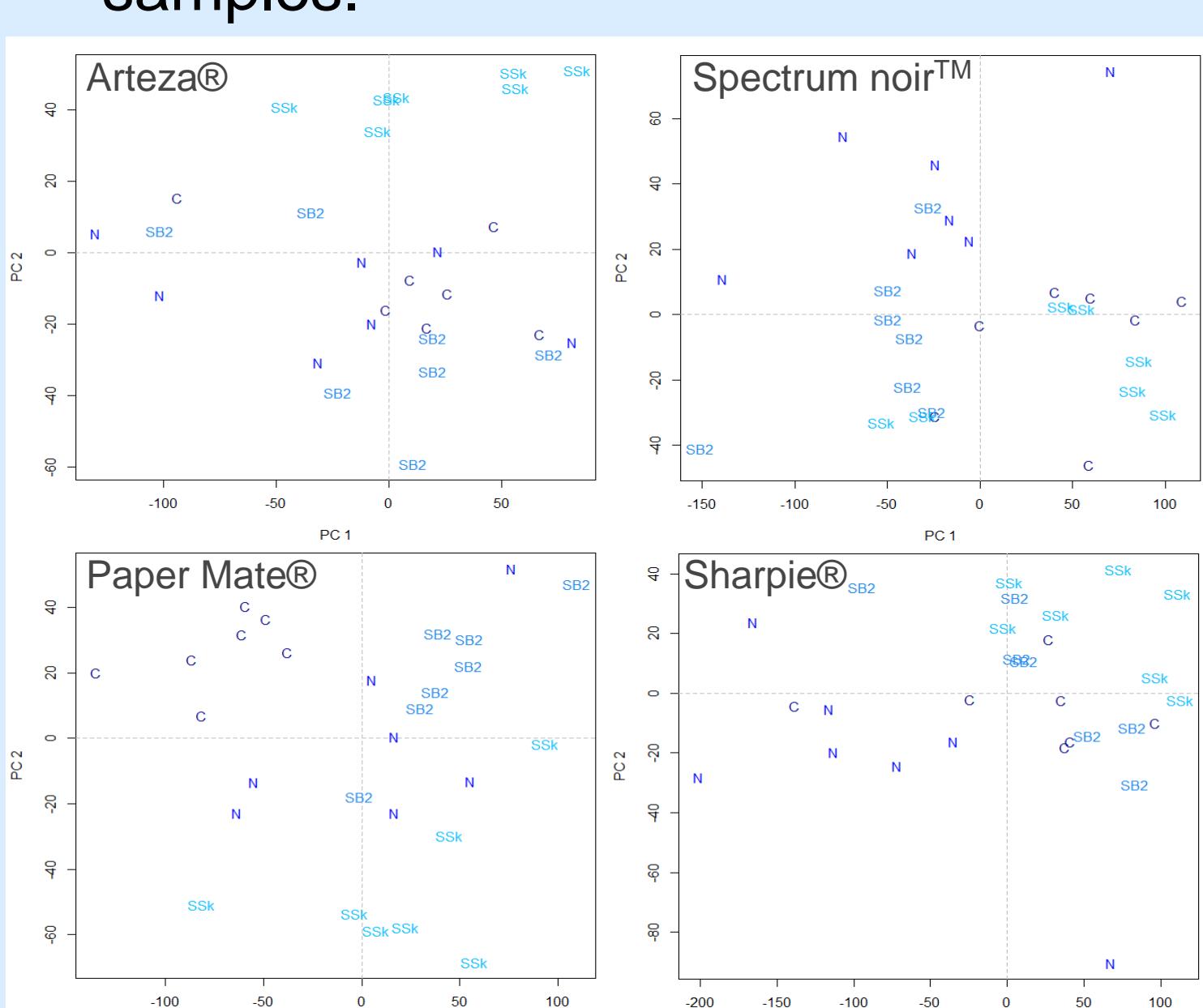
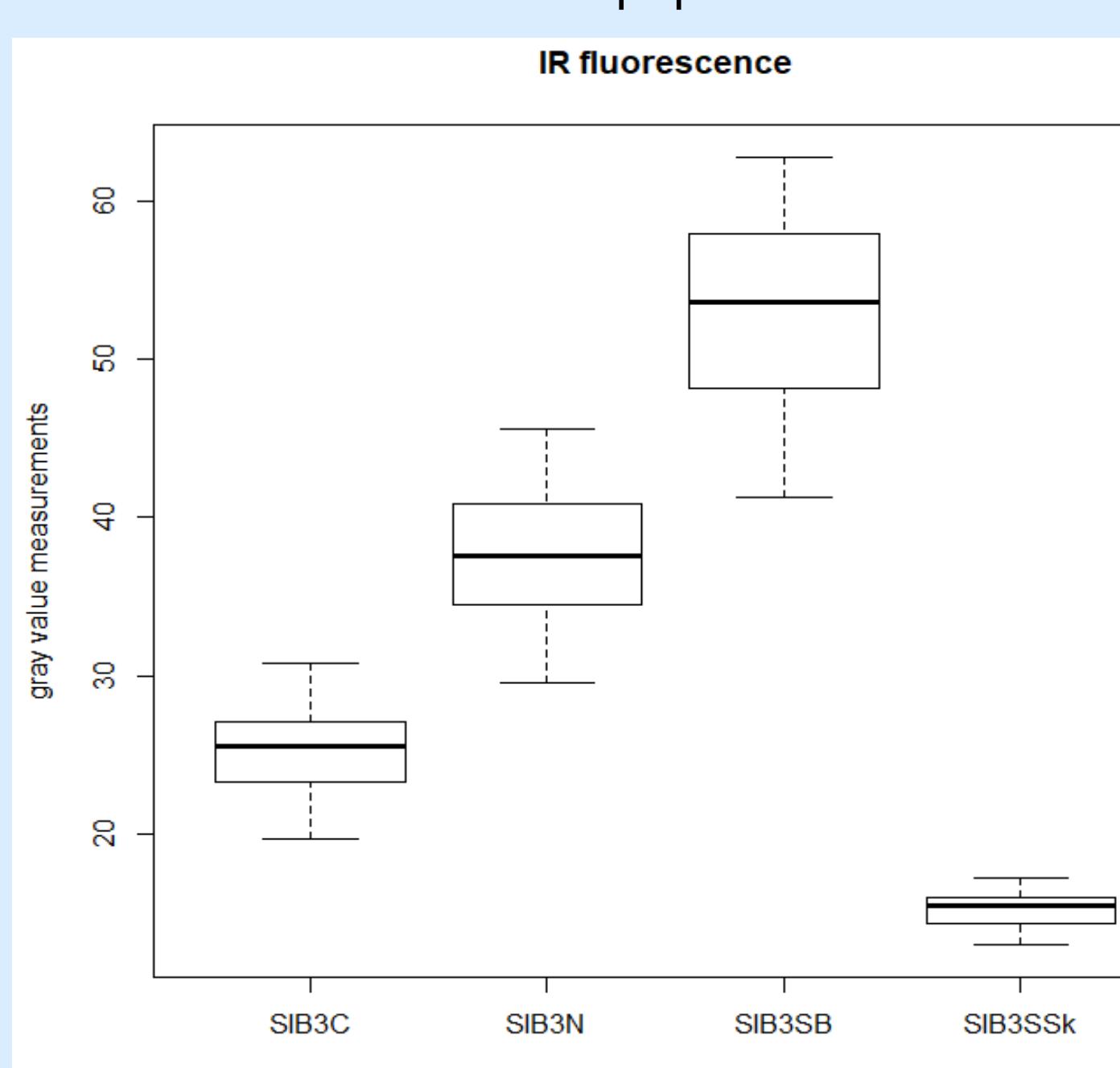


Figure 4: PC1 vs PC2 plots of 4 different blue markers from on different paper mediums.



Gray Value Analysis

- Artistic and non-artistic Black, blue, and yellow ink stroke samples analyzed thus far.
- Box plots of gray values useful for observing differences between paper mediums.
- One-Way ANOVA analysis of all black, blue, and yellow ink stroke samples indicated that differences in paper mediums affect gray values extracted.
- Source of lack of normality in gray value data sets needs to be further explored.

Figure 5: Gray value box plots of a blue ink stroke from Spectum noir™ using IR reflectance (above) and IR fluorescence (below).

Blended Ink Sample

- Visual analysis led to the possibility the blended ink sample being composed of a combination of a black, red, orange, yellow, and blue marker.
- Filtered light examination narrows down the hypothesized markers used to 7 markers from 3 different brands.

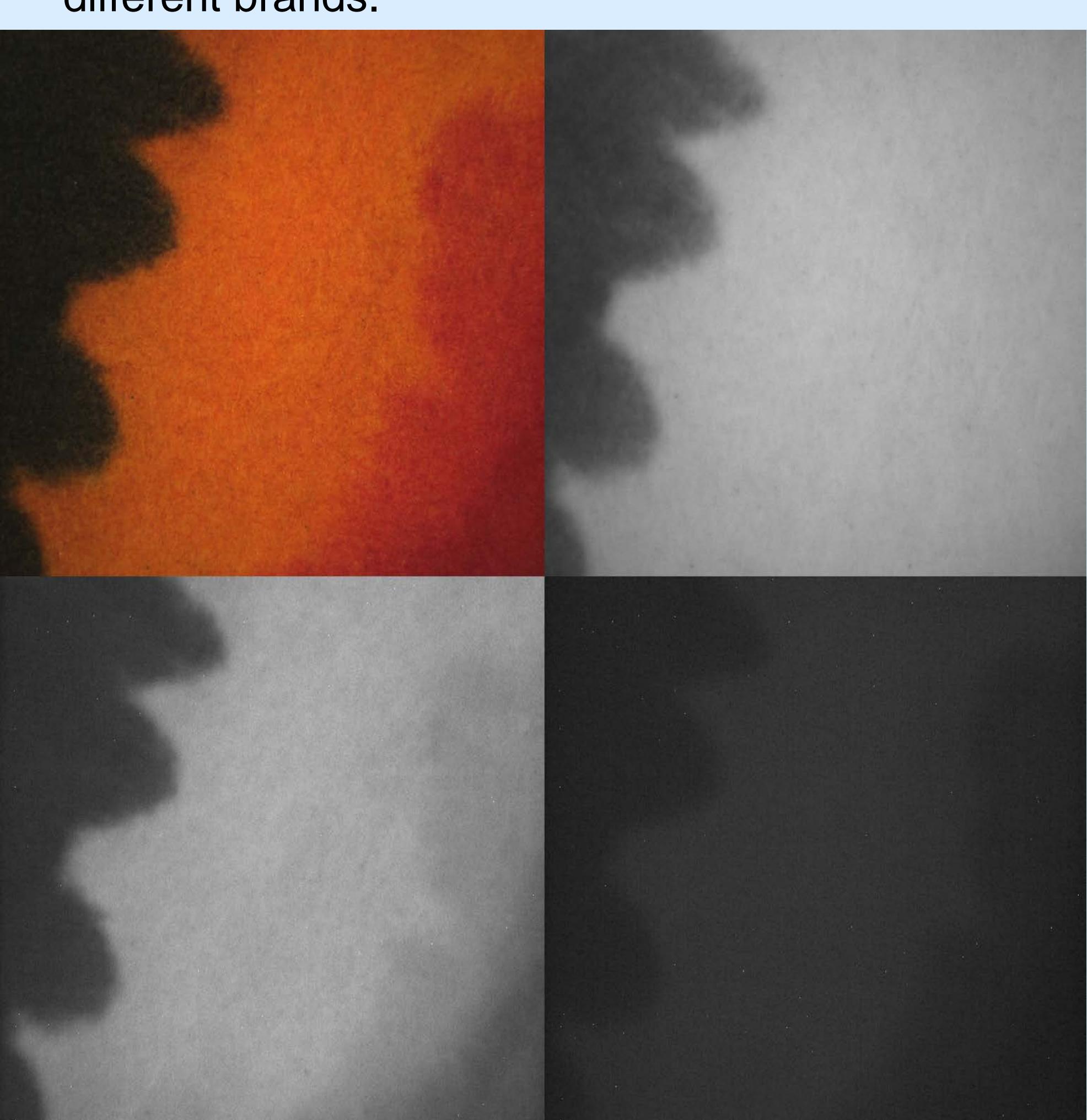


Figure 6: Orange section of the blended ink sample under different light filters.

CONCLUSIONS

- Filtered light examination and HSI reflectance spectra greatly enhances discrimination between samples.
- Differences in paper medium seen in visual analysis, filtered light examination, and HSI reflectance spectra.
- Gray value analysis and HSI confirm that paper influences the clustering of HSI reflectance data in black, yellow, and blue ink stroke samples.
- Future steps: Linear discriminant analysis on HSI PCA data to determine accuracy of classification.
- Currently it is hypothesized that the blended ink sample is composed of one of 2 black markers, one red marker, one of 2 orange markers, one yellow marker, and one blue marker.

ACKNOWLEDGEMENTS

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