



Article: Photoshop® Assisted Spectroscopy – An Economical and Non-Destructive Method for Tracking Color Shift

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Photoshop® Assisted Spectroscopy – An Economical and Non-Destructive Method for Tracking Color Shift

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Abstract

Many historically and culturally significant objects from the mid-to-late 20th century were created with media which contains light sensitive dyes that present problems for collection custodians and conservators. The conservation staff at the National Library of Medicine (NLM), National Institutes of Health, conducted a multi-phase project on the aging of ballpoint pen ink in a variety of enclosure types that ultimately culminated in the development of a new method to detect color shift in documents with light sensitive media. This article offers instructions on how to detect color shift in digitized materials using Photoshop® Assisted Spectroscopy.

Photoshop® Assisted Spectroscopy: a non-destructive method to track color shift

The National Library of Medicine (NLM) conservation staff developed Photoshop® Assisted Spectroscopy to study storage requirements for documents with sensitive media. The first part of this multi-phase study dealt with the destructive analysis of ballpoint pen ink using traditional analytical methods on weeded documents. The second phase moved towards digital methodologies using Photoshop software as an analytical tool. The third and final phase used Photoshop Assisted Spectroscopy to track color shift in ballpoint pen inks.

Phase 1 - Traditional Analytical Testing

The initial goal of this project, begun in 2005, was to determine the chemistry of ballpoint ink and to define accurate but simple methods to identify, house, and conserve ballpoint pen ink. At the time, the best practice for determining the nature of the ink was using spot tests from fixatives, which is subjective and leaves room for error (Bredereck, 1988). Based on visual inspection of ballpoint pen ink artwork and documents, NLM staff were aware that the color in different pens, even different batches of the same pen type, could shift differently while stored in the same environments. Some of the observed color shift occurred while the art was stored in a dark, cool, alkaline environment. This observation was supported by research in the forensics field, in which a substantial quantity of research has been done (Weyermann, 2006; Andrasko, 2001).

This phase focused on analysis of the ballpoint pen ink chemistry as it exists on historic paper documents with the intention to corroborate the subjective spot testing using chemical analysis and testing. For this testing, ballpoint ink from weeded historic documents was extracted into a fifty-fifty solution of pyridine and deionized water. Several traditional analytical methods including UV-Vis microspectrophotometry, Fourier transform infrared spectroscopy, and gas chromatography-mass spectrometry were performed on the extractions. The goal was to compile the resulting data and not only gauge the accuracy of the spot tests but also compare the historic

ink data to similar tests performed on modern inks. The methodology proved to be time consuming and extracting ink in large enough quantities from historic samples while minimizing factors such as paper type and extraneous ink interaction caused many samples to be unusable. These factors led the project team to seek out a more streamlined and non-destructive method.

Phase 2 - The Development of Photoshop Assisted Spectroscopy

The project transitioned from the use of traditional scientific analytical methods to an all-digital analysis, creating a way to assess degradation levels in ballpoint pen ink without the analytical equipment explored in phase one. At NLM, the conservation staff was assigned the task to determine the proper storage for the Marshall Nirenberg genetic code charts – a series of important documents in scientific history. The six charts in the collections of the National Library of Medicine’s History of Medicine Division contain original data from experiments that determined how protein sequence was dictated by the sequence of precursor ribonucleic acids (RNAs). As a result of the work that was recorded on the charts, Dr. Nirenberg was awarded the 1968 Nobel Prize in Physiology or Medicine. In 2011 the charts were scanned at 500 ppi using a Cruse Synchron Light Scanner to create high quality facsimiles. NLM conservators chose to use these scans for a secondary purpose – to attempt analysis of color shift in ink using the newly developed Photoshop Assisted Spectroscopy technique.

Summary of Photoshop Assisted Spectroscopy:

Photoshop Assisted Spectroscopy is one of many non-destructive analytical techniques available to detect color shift. This technique can be accomplished using only a scanner and software that allows the user to monitor red, green, and blue (RGB) values on a pixel-by-pixel basis. Adobe Photoshop CS 5 was used in this instance (Adobe Systems Incorporated, 2011).

Photoshop Assisted Spectroscopy is an analysis technique using numbers that represent color. The method allows the observer to pinpoint the exact location of each RGB triplet group on the object. The numbers are plotted on a 3-D graph in order to show the degree of color shift. The project team used a 3D graphing software (Nourian, 2014), which enables plotted data points to be viewed from any angle, and will automatically rotate the graph if desired. The third dimension allows the viewer to understand the direction in which the color is moving on the graph since the RGB values correspond easily to an XYZ axis. All axes are set with 0 as a minimum and 255 as a maximum in order to correspond to RGB values. Additionally, to increase readability, the X axis was set to display in red, the Y in green, and the Z in blue. As a result, color shift can be viewed in relation to the direction the ink is shifting based on the axis color it approaches (or moves away from). Because color is directly linked to chemical properties, these numbers do have meaning. With further study, it may be possible to link the RGB values to the array of chemical properties they represent.

Methodology Testing:

To achieve accuracy across the board while using this technique, it is imperative to have a properly calibrated scanner that can accurately represent the colors in the object. NLM conservation staff determined that monitor calibration and computer hardware are largely

irrelevant for analysis, though accurate monitor calibration does assist the user in visual distinction of color. Photoshop software relies on the RGB values and these do not inherently change even if the image file is opened on different computers.

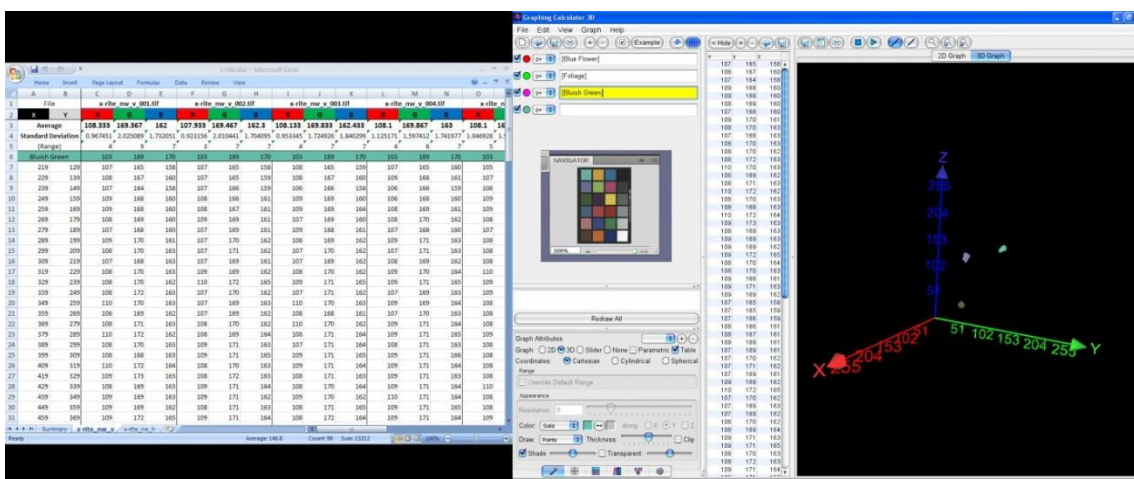


Fig. 1. A screenshot of the analysis of the Color Checker Card (middle). The left side shows the excel file used for data collection, the right side shows the points graphed on a 3D axis. Note the cluster shape of the graphed data points.

In initial scans to test the technique, a color-checker card was scanned repeatedly in four different positions on the scanner platen and then analyzed in Photoshop software in order to answer several questions:

- 1) How much variation is present from pixel-to-pixel in the scanner (keeping in mind that the color should be even throughout)?
- 2) How much variation is present from a 'cold' scanner bulb to a 'hot' scanner bulb?
- 3) How much variation is present when different scanner quadrants are used?

After scanning, the RGB values were recorded for the same pixels across a series of images. The average of the pixel variation was compared to the standard RGB values provided by the color checker card vendor. The degree of variation from pixel-to-pixel within the same scan was also recorded in a spreadsheet. The scanner portrayed the image accurately in all quadrants and under both hot and cold bulb conditions.

Next, the team focused on analyzing an ink line. Two lines of Skilcraft ink in blue and black were drawn on a weeded scrap of 1960s Addison-Wesley paper. The sample was scanned then artificially aged under UV light for 72 hours. Data was collected from both the initial and final scans and graphed on a 3D axis.

When the color-checker card RGB values are graphed on a 3D axis, the graphed points appear as clusters. This is due to the evenness of color application and the lack of variation from pixel-to-pixel. Hand-applied ink graphs show a linear pattern which differs from the color checker card clusters. This difference can be attributed to the variation in ballpoint ink components and the thickness of the ink on the paper. This linear pattern does not make color shift any less detectable.

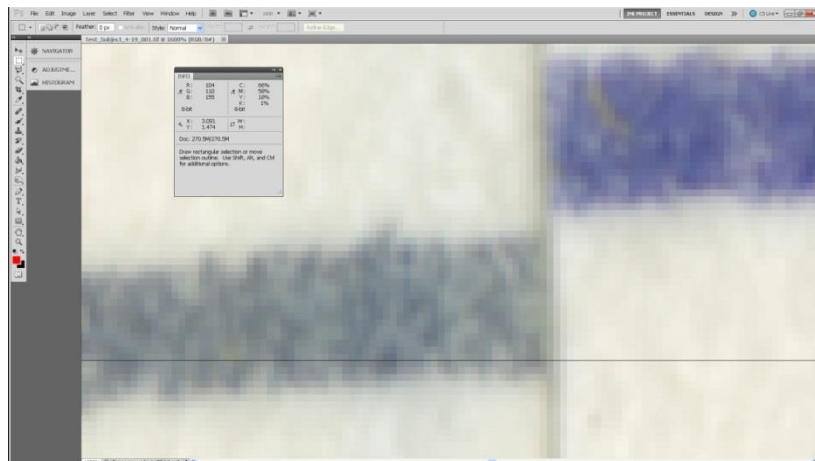


Fig. 2. This is the first ‘real’ ink line examined using Photoshop Assisted Spectroscopy. The right side shows the control sample and the left side the sample after 72 hours of UV exposure.

As a result of these tests, the NLM team determined that it is possible to track color shift using Photoshop software. However, tracking this process on an item in a more realistic environment presents additional variables and is addressed in phase 3 of the project.

Phase 3

The goal during this phase was to determine appropriate storage environments for ballpoint pen using the Photoshop Assisted Spectroscopy technique. To start, the project team decided to expand the 72 hour test from earlier to include a series of different sample types that were aged in a variety of environmental conditions.

Samples were created using different types of paper, ballpoint inks, and enclosure options. The samples were exposed to different lighting for a period of time and evaluated using Photoshop Assisted Spectroscopy. The samples were scanned before testing and rescanned at intervals throughout the project. Analysis from the scanned images reveals the relative degree of color shift based on the different environmental conditions. Ideal storage conditions were determined for the charts and valuable information gleaned regarding enclosure types for other ballpoint documents.

Methodology for Data Collection:

An initial scan at 1200 dpi on an Epson 10000 XL scanner was made of each sample set. All files were saved in the .tif format. Each sample set was then exposed under the assigned lighting environment and scanned weekly for a total exposure period of two months. Samples were placed in the same quadrant of the scanner with the same orientation for all scans.

The scanned images were opened in Photoshop software for data collection. No editing was done to the files. Using the ‘Info’ window, set to RGB values and XY coordinates, RGB values were collected along each ink line intended for analysis. Data was recorded from the

middle of the ink line, moving ten pixels along the X axis between each point. Data was stored in a spreadsheet. The scans remain available and are unaltered, so additional data may be collected.

The collected data points were plotted on a 3D axis. In order to demonstrate the degree of color shift, the data points from the initial scan were plotted on the graph with the data points from the final scan. The graphed color corresponds roughly to the original ink color while the other data points, representing the shifted ink, are displayed in gray.

After all of the sample data was plotted on 3D graphs, the color shift for each ink line was evaluated and measured. Color shift was rated minor, moderate, or major based on visual assessment by team members. The results were subsequently compiled and compared. Ink colors were examined separately from one another and evaluated in the following categories: lighting type, paper type, and enclosure type. In addition to visual analysis, Delta-E calculations for color change were done using the Cie94 analysis formula (Zack, 2014). In most instances, the Delta-E calculations corroborated the results of the visual analysis.

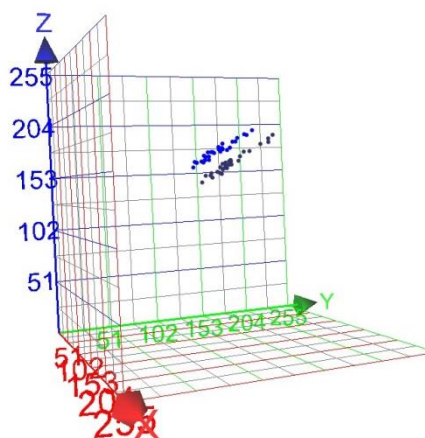


Fig. 3. The bright blue line displays the gathered data for the initial, unexposed ink. The gray line shows the data for the shifted ink. The graph can be rotated on a computer screen so it can be viewed at different angles.

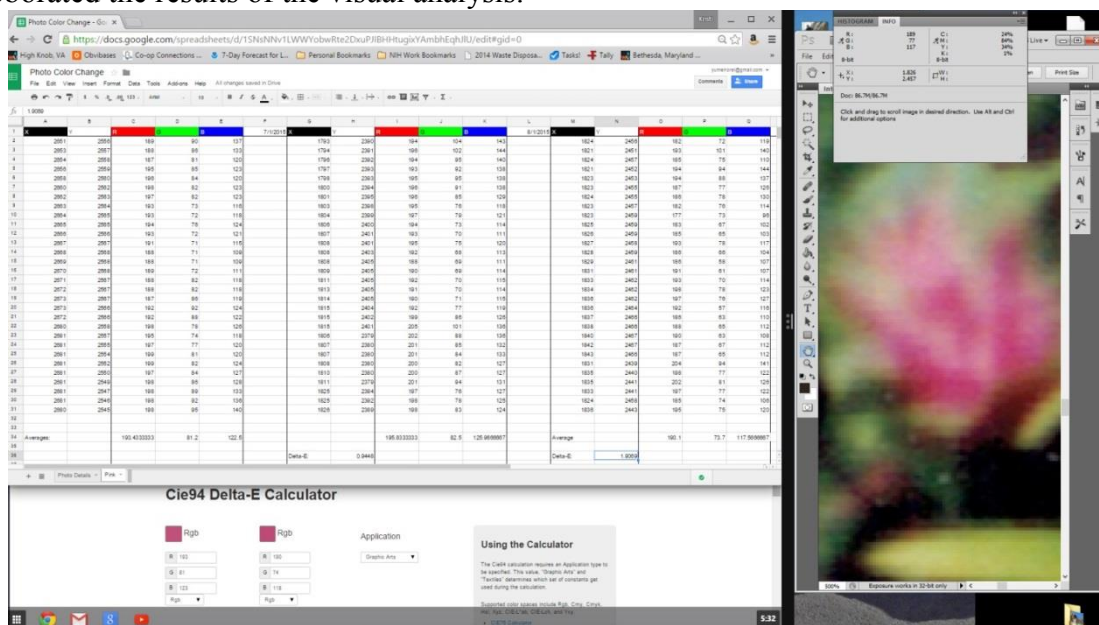


Fig. 4. An analysis of a color photograph exposed to daylight over a period of two months shows color shift with a Delta-E value of 0.09448 in the first month and 1.9059 at the end of the second. The latter is quickly approaching the level of shift generally agreed to be perceptually noticeable by the human eye (2.0). Image created by NLM staff.

Conclusions and Further Study:

Image-editing software, such as Photoshop, is more affordable than traditional analytical equipment and can have multiple applications in an institutional setting. While scanning specifications must be maintained, the methodology is easy to learn and replicate. It is recommended that scanning details are kept in the metadata to ensure that the initial settings are stored for comparison in the future.

Ballpoint pen ink displays in a linear manner when the test results are plotted on a 3D graph. NLM conservators noticed that the color shift for ballpoint pen ink will sometimes be parallel to the original graphed ink line, but other times will shift at an angle to the original ink line. While this project does not assess the reasons for this difference in shift pattern, it is an interesting observation that could be studied further in the future. Linking RGB values displayed in Photoshop software to distinct ink components also requires further study and validation.

Other applications include use as a monitoring tool. Collection custodians may use Photoshop Assisted Spectroscopy to monitor color shift using previously scanned digital collections as long as the imaging devices have been properly calibrated. For example, when collections are initially scanned, this technique could be used on any subsequent scans to assess the condition of the colors. The technique could be applied to many types of media as it relies purely on color shift rather than on the specific chemistry of the ink.

Additionally, there is the opportunity for the creation of a Photoshop software plug-in to streamline the data collection for larger sample sets. With such a plug-in, the data collection process would be more automated for the tracking of color shift on a larger scale over time. NLM staff are now aware of certain microscope imaging software that may provide the desired data collection functionality. However, this option has not yet been explored and thus details are not included in this publication.

Photoshop Assisted Spectroscopy was developed to assess the suitability of select enclosures specifically for the Skilcraft brand ballpoint ink on the Nirenberg Genetic Code Charts. As a result of the three phases of the study, NLM conservation staff recommend that blue, black, and red Skilcraft ballpoint inks be stored in either an anoxic or hypoxic enclosures and in the dark. When placed on exhibit, LED lighting is most desirable. While anoxia appears to be beneficial for many types of media (Thomas, 2011), due to variations in ballpoint ink formulae (Weyermann, 2005), each different ink should be evaluated on a case-by-case basis.

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Notes

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Appendix A

A quick how-to guide to Photoshop Assisted Spectroscopy:

- Decide on desired scan resolution (NLM used 1200 dpi).
- Scan image, save file as .TIF
- Open scan in Photoshop. Zoom in on section to be analyzed
- Open 'info' window
 - Collect data
 - Move mouse over desired pixel. RGB and XY values will display in 'Info' window
 - Record RGB values and XY axis data into separate spreadsheet
 - Tip: It is useful to Alt-tab away from Photoshop instead of clicking away – that way the values remain in the 'info' window.
- Repeat with future scans. Compare later scans with initial scan to determine degree of shift.
- If desired, graph on 3-D axis
- May also wish to calculate Delta-E to determine significance of shift.