Quantitative Assessment of Watercolor Reproduction

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Keywords

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Abstract

Creating fine watercolor paintings requires considerable artistic proficiency. Likewise, quality reproduction of watercolor paintings demands similar proficiency from a printer. The purpose of this study was to quantitatively measure the color accuracy of watercolor paintings when they are reproduced. Furthermore, this study compared the quantitative aspects of color to perceived differences in color.

Introduction

To access the color reproduction of a painting in a quantitative way, the colors of the painting need to be defined and measured. To perform this experiment colors were sampled from the watercolor painting "Downtown Rochester" by Rochester Institute of Technology Professor Luvon Sheppard. To reproduce the colors of professor Sheppard's paintings, the original was digitally captured by a scanner. Next, an experienced artist determined which colors in the painting were important to ensure faithful reproduction. Using Adobe Photoshop, these colors were then sampled and pasted into a synthetic target. The CIELAB values of the A2B transform from the scanner profile of each of the target patches were recorded. These CIELAB values served as a reference to determine the colorimetric accuracy between the monitor and the print. Subsequently, the synthetic target was output to a digital printer, and the target patches were measured to determine ΔE between the reference and the reproduction. The relationship between the onscreen appearance of a painting and its reproduction was also studied.

Literature Review

To enhance their creative potential artists have quantified color for almost a century. A pioneer in the quest to define color in art was Albert Munsell. In 1905, Munsell developed a color system that quantified color both numerically and through physical exemplification. The Munsell system divided color into three attributes hue, value and chroma. Munsell thought that to use color artistically, the artist must first separate and define color (Berns, 2000, pp. 37-39).

Similarly, using color managed workflows, printers need to quantify color to predict how well the reproduction will match the original. Once an image is converted to a digital file the printer must be able to accurately predict the transformation of the colors of the original to the colors of the reproduction. One method to quantitatively measure the accuracy of a reproduction is to measure specifically defined colors within the reproduction. Chung and Shimamura (2001) comment "The magnitude of ΔE between two simple fields, e.g., flat colors or logo colors, correlates well with visual assessment. On the other hand, Chung and Shimamura (2001) state there is no easy way to assess color difference quantitatively between two complex images, e.g., a pictorial color proof and its corresponding press sheet" (p. 1). Additionally, Field (1999) notes that the critical aspects of the color reproduction cannot be measured. The acceptance of the reproduction must always be based on the viewer (p. 374). Therefore, even though the visual perception of flat fields of color correlates well with visual perception, the unique nature of complex images limits their use.

Methodology

One method to bridge the gap between colorimetric measurement and viewer perception is to create a flat field target from the colors of an image that is based on colors a viewer deems important to the image in question. This target can then be reproduced, and the measured values of the reproduced target can be compared to the reference values. If the selection of the colors that make up the target are important to the faithful reproduction of the original, the measured ΔE values should correlate well with the visual perception of the reproduced image.

The methodology of this study consists of two parts. The first part is the creation of a synthetic target and the second part is the measurement of the colorimetric accuracy of that target.

Part A: construction of synthetic test target:

1. Scan original painting using Scitex EverSmart scanner.
2. Using Photoshop, assign scanner profile, EverSmart_fuji.icc, to the scanned RGB image.
3. Create a new RGB document 5 x 7 inches at 100dpi.
4. Assign the EverSmart_fuji.icc profile to the new document.
5. Using guides divide the document into thirty-five 1-inch blocks.

6. Sample colors of interest from the scan of the painting with Photoshop's eyedropper tool, and fill each block of the document (Figure 1).
7. In Photoshop, convert the document to Lab color using a relative colorimetric rendering intent.
8. Record the CIELAB values of each of the blocks. These will serve as the reference values.

Part B: measurement of color difference after reproduction:

1. Put the scan of the painting and the scene-specific synthetic target on the same test form.
2. Convert the test form to CMYK for the DocuColor using the X2060_GM_032902.icc profile with relative colorimetric rendering.
3. Output the test form to the DocuColor 2060.
4. Measure the Lab values from the synthetic target that is reproduced and compare to the original reference values.
5. Plot ΔE using the a* b* diagram to determine the source of color difference.
6. Compare the ΔE with the perceived visual difference.

Results and Discussion

Figure 2 shows the completed target that was printed. Table 1 shows the ΔE that was calculated after measuring each patch of the target after output on the DocuColor 2060.

Figure 1: Measurement of Lab values.

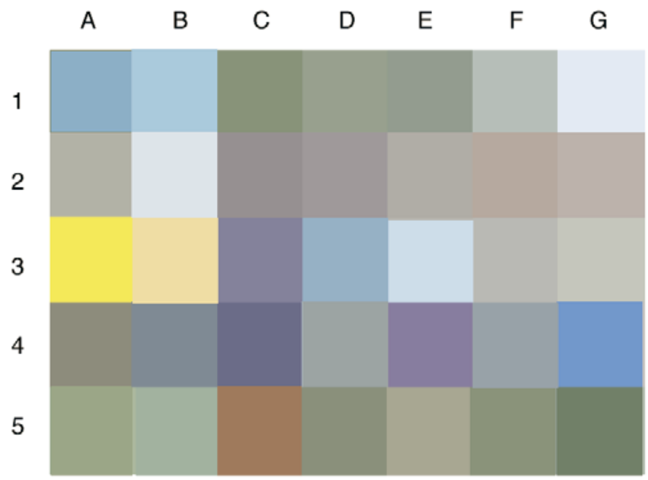

Figure 2: Synthetic target.

	A	B	C	D	E	F	G
1	11.8	9.2	12.6	11.6	10.0	4.8	5.6
2	6.0	4.7	15.9	8.4	6.4	8.0	4.4
3	19.8	14.9	11.8	9.1	5.9	4.2	3.9
4	12.8	11.4	12.8	8.2	12.4	7.7	14.9
5	12.0	8.2	13.6	12.5	9.3	11.9	11.4

Table 1: ΔE of the reproduced synthetic target.

Values over 10 ΔE are in red, values between 5 and 10 ΔE are in yellow, and values under 5 ΔE are in green.

The average ΔE of all patches was 10, which is considered a strong color difference. Comparing the target in Figure 1 to the ΔE in Table 1 shows larger ΔE values occurred in the higher chroma colors, while lower ΔE values occurred in colors near neutral. For example, Patch G3, a warm gray color, had the lowest ΔE, 3.9, while patch A3, a bright yellow color, had the highest ΔE, 19.8. Figure 2 shows an a*b* plot of the reference and the reproduced values. The plot shows greater ΔE in the higher chroma patches of the synthetic target.

To explore further, the reference values of the synthetic target were plotted inside the output gamut of the DocuColor using CHROMiX ColorThink. Figure 3 shows the comparison of the gamut of the DocuColor profile to the reference values of the target revealed that the G3 (blue) and A3 (yellow) patches were outside of the gamut of the DocuColor. Additionally, several of the reference colors were near the edge of the DocuColor's gamut. Excluding the out of gamut A3 and G4 patches, reduced the ΔE to 9.5.

At first this did not seem possible because the color gamut of a watercolor painting should be well inside the gamut of the DocuColor. A plausible explanation is that the conversion to the DocuColor profile used the Scitex Eversmart profile as the source space. The EverSmart profile was created with a Fujicolor IT8.7/2 target, which used photographic dyes that have different spectral reflectance curves than watercolor paints. This could account for the fact that some of the reference color patches were not converted in a way that was consistent with an relative colorimetric rendering intent. Another assignable cause of variation for the larger than expected ΔE, was device calibration. No single ΔE was under 3.9, indicating that the scanner calibration could have been off by that much.

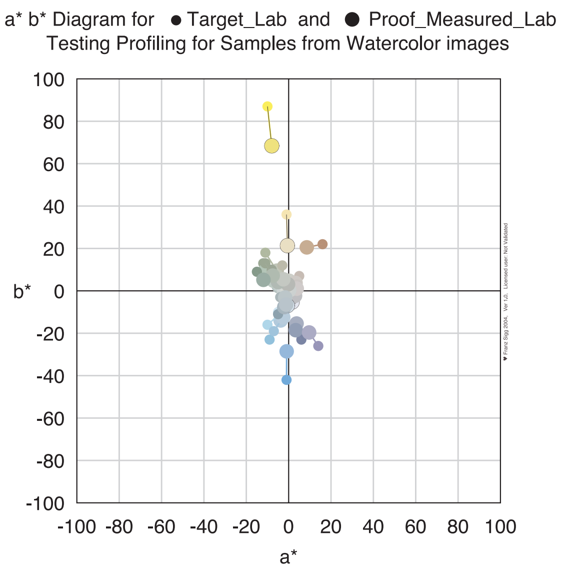

*Figure 2: a*b* plot of reference and reproduced colors.*

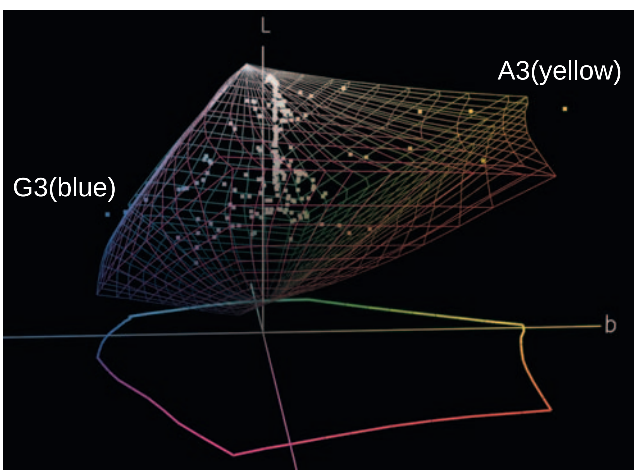

Figure 3: Reference CIELAB values of target plotted on DocuColor 2060 gamut.

Since the synthetic target that is used as the reference was created in Photoshop, all subsequent visual comparisons are made between the monitor and the reproduction. Figure 4 shows a representation of the difference in ΔE between the monitor and the reproduction. To make this illustration, the measured Lab values were entered into Photoshop's color picker. Therefore, even though the actual color rendering may not be accurate, the difference between the slices represents the actual difference that was measured. Again, to demonstrate the difference in appearance, sections of the painting were made by cutting and pasting pieces of the document converted to the DocuColor profile back into the RGB document with the EverSmart profile.

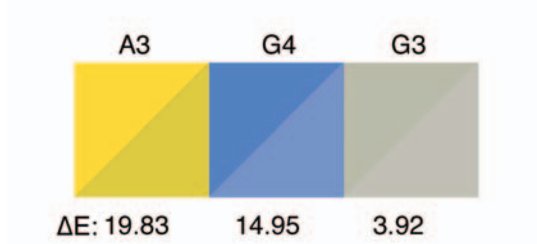

Figure 4: Simulated comparison between monitor and reproduction.

A visual comparison between the monitor and the reproduction revealed that the most noticeable color difference occurred in the G4 (blue) patch. This difference correlates well with the measured ΔE of 15. The A3 (yellow) patch that had the highest ΔE of 19.8 also showed a strong visual difference between the reproduction and the monitor; however, the perceived change was less than the G4 (blue) patch. This represents an inconsistency between visual perception and ΔE. However, the G3 (warm gray) patch had the lowest ΔE 3.9, and it was perceived to be almost the same in color between the monitor and the reproduction, with the monitor being slightly lighter in appearance.

When compared to the original watercolor painting, the reproduction had a magenta cast that was most noticeable in the blue sky. However, the monitor closely matched the reproduction, indicating that the change in color was due to scanner calibration. Furthermore, a comparison between the monitor and the reproduction revealed less of a perceived difference between the painting than the synthetic target. This may be because the painting is a more complex image than the target, thus increasing the perceptual threshold. This would indicate that the viewer is more sensitive to changes in a flat field target than a complex image, therefore making the target a sensitive visual gauge as well as a colorimetric tool.

Conclusion

Quantitative analysis of fine art reproduction is possible when color patches of a synthetic target are reproduced along with the artwork. The assumption is that what happens to the colors of the artwork can be quantified by analyzing the color patches of the synthetic target. Using colors from the artwork itself and transforming these visual elements into CIELAB values with an input ICC profile represents an innovative approach to tone and color analysis.

To enhance the correlation between visual perception and colorimetric measurement, it is recommended that further study be conducted to determine criteria for the selection target colors. For example, five achromatic patches ranging from highlight, to midtone, to shadow should be included to study tone reproduction of the watercolor reproduction.

Furthermore, the nature of the target used to generate the source profile should be evaluated to ensure that it represents the colorants and the density range of a watercolor painting.

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Painting 'Downtown Rochester' courtesy of Luvon Sheppard.