Addressing the Problems of Color Science and Management in Toner-based Digital Print

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Abstract

There are long standing problems in achieving accurate and consistent colors in digital laser printers and color copiers. Despite efforts of incorporating a standardizing ICC profile in digital color equipment, the ICC profile is still subject to various internal and external factors. The inherent conflicts of color management are associated with the calibration of color printers, the differences between the monitor and the actual CMYK prints, soft color proofing on the RGB monitor, inconsistent printer settings over time, variation of colors in different printers and color inconsistencies in repeated printing.

This paper aims to address these problems and presents a novel solution for them. The solution was developed based on both objective and subjective color comparison and Artificial Intelligence technology. It is used to calibrate and stabilize digital printers in a quick and easy fashion by means of ICC profiles.

Introduction

With the emergence of open publishing systems based on standard computing platforms, it has become even more complex to standardize colors between different devices. Current available technologies try to solve such color problems, but none of them have provided any means to verify the accuracy of the colors printed. Recent technological breakthroughs in Artificial Intelligence can detect small yet significant differences of color and correct them in an automated fashion. Used together with a color verification method for printed colors, this effective combination can revolutionize the color management industry.

Since the inception of DTP in the 80's, creative professionals have struggled with ensuring the color desired by their clients matches the printed output. Synchronizing the two has been the mission of color management technology[3] for the past two decades. Adoption of color management among printers is fairly common, to a much lesser extent for creative professionals and publishers. You would hardly find a spectrophotometer in a small printer, copy-shop or a design agency. Yet everyone in the graphic arts industry demands and expects accurate and consistent colors. But as difficult as color management is to implement in the commercial printing industry, for graphic designers – it's worse. This is probably because of the over-reliance on laser proofs. To them, "Color Management" simply means, "match the laser copy."

The following paper begins with a discussion of color standardization issues, moving from there to color characteristics and comparison. It then presents a solution in the form of the Intelligent Color Calibration System and explains its methodology. A section on the means of verifying the results of the system is then presented. Followed by a conclusion of the system as an ideal solution to addressing color science and management on digital toner-based printers.

Color Standardization Issues

In general, color standardization means ensuring that color is processed consistently throughout the entire color reproduction process. Color laser copiers, laser printers and professional digital press systems create color images by combining colorants such as pigments or dyes in response to image data. For example, conventional color systems produce an image by combining cyan, magenta, yellow and black (CMYK) colorants.[6] The same CMYK image data printed using different color reproduction systems will produce images with different color characteristics. The different color characteristics are due to the different absorption spectra of the colorants, different amounts (densities) of the colorants, and different mixing characteristics (trapping) of the colorants. The main causes of differences in color characteristics include temperature changes, humidity changes, changes in paper, changes in toner/ink, and usage, etc.

The biggest question is – how and when does one calibrate the printer? Every user of a digital color printer experiences the same set of difficulties when it comes to ensuring accurate color production. From input to output, there will always be inherent conflicts relating to color printing.

- *Soft proof is not hard proof*
  Referring color on an RGB monitor is not reliable.
- *WYSIWYG – What You See Isn't What You Get*
  What is seen on the monitor is never what is produced on a CMYK print.
- *Scanners – garbage in, garbage out*
  Image output quality is only as good as its input quality.

- *Different color output*
  The same image printed on different printers appears different.
- *Inconsistent color output*
  Color toner is notoriously unstable. Toner-based color copiers' and printers' settings and color characteristics are subject to instabilities brought about by environmental factors like temperature and humidity, and mechanical factors like toner variations and machine drift.
- *Color confidence*
  There is as yet no assurance or means of verification after a color calibration exercise is completed. There are numerous 'one-off' ways to calibrate devices, but the environment in which a printer operates constantly fluctuates. There is currently no way to ensure color consistency from day to day.
- *Knowledge and expertise*
  Accurately manipulating color settings requires lots of experience and knowledge.
- *ICC profiles*
  The color management system architecture and components provided by ICC profiles are, arguably, lacking in that they are too static a management method for something as changeable as accurate color output. A lack of easy verification and testing procedures sometimes leave ICC profiles and CMMs in people's minds as overly complicated and debatable promises. They do not as yet offer assurance of a printer's ability to *consistently* produce accurate color.

Color Characteristics and Comparison

The perception of color relies on three elements: the light source, object and observer.[1] From a scientific viewpoint, an object does not have inherent color. The perception of color is created solely by the reflection of light from an object.[2] These physical characteristics can be established using a color measurement device. However, no matter what kind of measurement technologies are used, the results should be consistent with visual assessment because the human eye is the final, and most important, judge of color. The way a particular color is perceived usually differs from the way it can be objectively measured.

Objective Color Comparison

Objective color comparison always requires the use of devices to measure a color compared against a reference target. Currently, the devices used for measuring and standardizing color include spectrophotometers, colorimeters, densitometers, digital cameras, and scanners. The advantage of objective color comparison is that it provides reproducible data regarding the difference between two colors. The disadvantage is that the data generated may not correlate with the human eye's perception of color.

Subjective Color Comparison

The human eye evaluates color through subjective color comparison. Subjective color comparison compares a printed color with a reference color visually. A person can tell the difference between two colors qualitatively. The advantage of this comparison is that it provides information on how the color is perceived which, arguably, is the only thing that really matters. The disadvantage is, however, that it relies on the opinion of an observer and may well result in disagreement between observers.

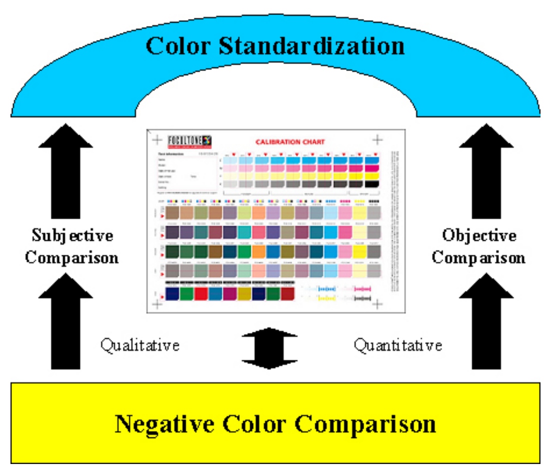

Figure 1. Negative Color Comparison

Negative Color Comparison

Negative Color Comparison (Fig. 1) is the analysis of color by evaluating a color's deviation from a target reference through their color difference. It uses the foundation of the two basic forms of color comparison – subjective and objective – to analyze colors.

On the qualitative front, it compares color like the human eye does. While it is a fact that the human eye cannot measure colors accurately, it can accurately compare between colors. Two individuals looking at a single color will see it differently, and these two individuals looking at two different colors will still see each of them differently. But – they will see the difference between the two colors with about the same degree of accuracy. What is important here is that individuals experience identical levels of difference when looking at colors.

Quantitatively, Artificial Intelligence uses Negative Color Comparison to assign data values to detected color variances,[8] thereby enabling data-driven color measurement.

Intelligent Color Calibration System (ICCS)

The application/program is an Adobe Photoshop plug-in that incorporates advanced Artificial Intelligence and Negative Color Comparison to detect color variance and contamination in digital printers. The system corrects these color imperfections by creating new ICC profiles for the printers.

Color verification is provided through the Focoltone Calibration Chart.

The enabling technology of ICCS was developed based on Artificial Intelligence. It provides a novel method for comparing printed colors against reference colors to assess and correct printer color characteristics.

To begin, a user prints out a Test Sheet of colors (Fig. 2) and compares it against the Focoltone Calibration Chart (Fig. 3). He then scans a composite (Fig. 4 of the Test Sheet and the Focoltone Color Calibration Chart.

Figure 2. Focoltone Test Sheet

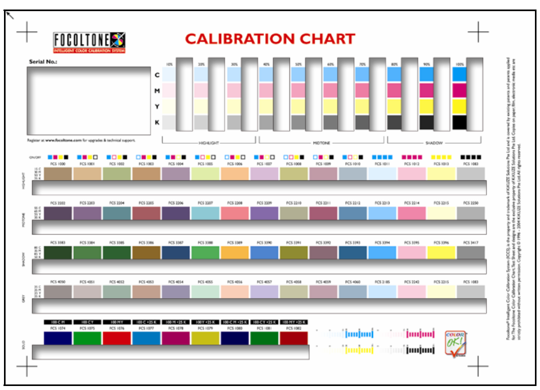

Figure 3. Focoltone Calibration Chart

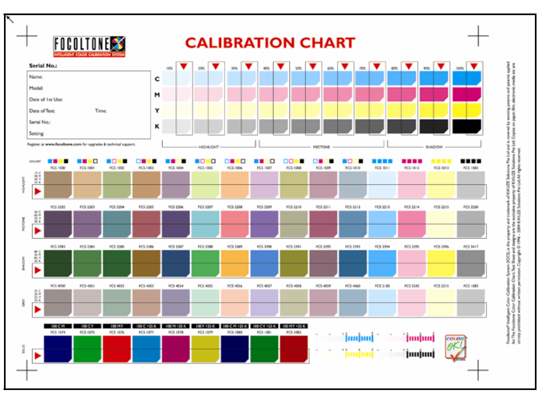

Figure 4. Test Sheet and Calibration Chart composite

ICCS extracts color data from the scanned image of the Test Sheet of colors and Calibration Chart, performing a 'compare-and-contrast' negative comparison analysis of the Test Sheet and Calibration Chart to determine the printer's color variance levels. The Test Sheet data tells the program how a printer is processing and producing the color data sent to it, while the Calibration Chart tells the program what the color data should be.

When the Test Sheet is scanned together with the Focoltone Calibration Chart, the colors on the Chart are defined as zero. The program picks up differences in the Test Sheet colors and converts these into numeric values (Fig. 5).

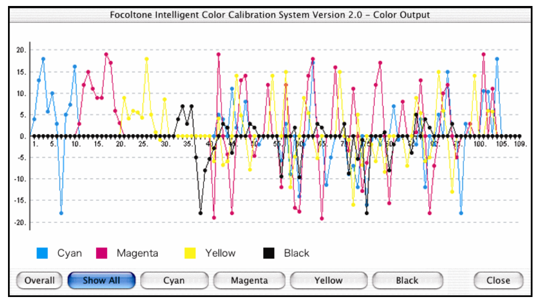

Figure 5. Color analysis before calibration

The Y-axis represents detected percentage deviation from the zero value after Focoltone ICCS analyzes the color pair. The Y-axis zero value indicates no color difference from the Focoltone Calibration Chart. The X-axis numbers correspond to the color patches on the Calibration Chart and/or Test Sheet. The lines show the deviation of each Test Sheet color from the Calibration Chart color.

When the plot points are above the X-axis (Fig. 6), it means Focoltone ICCS has detected color differences indicating a color's color density is too high, i.e. the color is too heavy. The inverse applies when the plot points fall below the X-axis (Fig. 7).

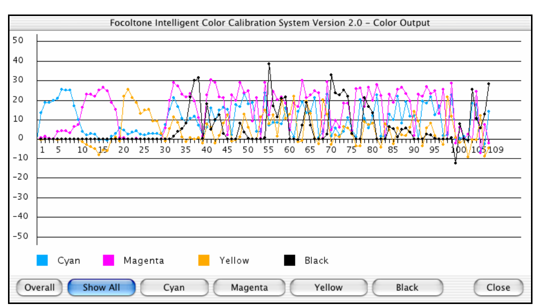

Figure 6. Color analysis of colors too heavy

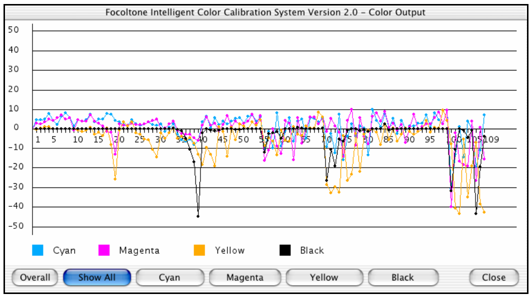

Figure 7. Color analysis of colors too light

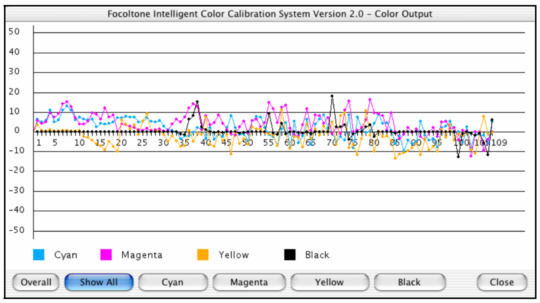

Figure 8. Color analysis after calibration

Using this data, the ICCS program refines the printer's ICC profile to bring it closer to accurate CMYK output (Fig. 8). Actual results may vary.

Focoltone Calibration Chart

The Focoltone Calibration Chart (Fig. 3) is printed on 250gsm art card. Every piece of the Calibration Chart undergoes stringent production and quality checking through a specially-created detection software that measures color accuracy and deviation on the Calibration Chart from offset CMYK standards.

It carries CMYK single, solid, mid-tone, shadow and gray colors. These colors are specially selected to cover a wide spectrum of commonly printed single, solid and mid-tone colors for greater accuracy in normal printing.

Most other color management tools measure using single colors and solid colors These are not the most common colors used in printing though. The bulk of problems come from printing mid-tone colors when one or more of the four process colors do not show the correct values.

By stretching the 'zero' color value of the Calibration Chart across a wide range of commonly used CMYK colors, the CMYK gamut is comprehensively represented through the chart.

Verifiable Results

When using other systems, users often have no means to verify the color calibration results. With ICCS, a user has two ways to verify the performance of a printer calibration.

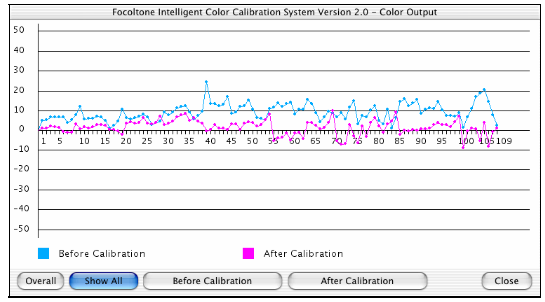

Figure 9. 2nd to 1st cycle comparison

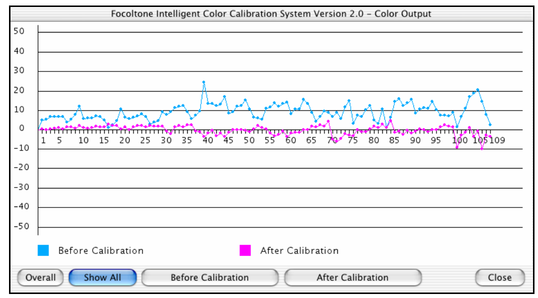

Figure 10. 3rd to 1st cycle comparison: shows improvements compared to the 2nd cycle (Fig. 9)

The Comparison Chart (Figs. 9 and 10) shows the user the most recent color adjustments made compared to the system's 1st cycle results.

The cyan line represents the color analysis from the first analysis. The magenta line represents the color analysis of the most recent analysis. It provides an easily understandable method of verifying the effectiveness of a calibration.

The other method of verification is through the Focoltone Calibration Chart.

The Chart acts as an easy-to-use verification tool. Comparing a Test Sheet printed on a calibrated printer against the Calibration Chart allows the user to visually verify the printer's color performance as compared against a high-quality print. This color verification is uncomplicated and highly relevant as the human eye is the ultimate and most important judge of color.

Conclusion

ICCS is a novel method of calibrating and stabilizing digital printers in a quick and easy fashion using a new ICC profile. By using a hardcopy target reference and Negative Color Comparison to analyze colors automatically, the usual complications of color calibration for printers are avoided, resulting in an effective system that makes editing ICC profiles easy for the color-concerned individual. Thereby providing a solution to address the problems of color science and management in digital print.

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Biography

Winson Lan is the founder of a group of print and color management solutions companies. He acquired Focoltone International Limited (UK) in 1992. Building on Focoltone's original two patents in CMYK process colors, Winson created a solution using Artificial Intelligence to manage the output of digital color printers and copiers. His research interests include digital device color calibration and improvements to existing digital printing. He holds a Master Degree in Entrepreneurship from the Asian Institute of Management.