Intelligent Color Calibration System (ICCS)

A Practical Solution to Colour Print Standardisation
by Focoltone® Colour System

Technical White Paper

Part 1 – Introduction
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FOCOLTONE

is a division of

KiKUZE

KiKUZE Solutions
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EXECUTIVE OVERVIEW

Since mid 1990, a number of color management products were introduced in the market. However, none of them has achieved any real market success.

There are some inherent conflicts related to color printing:

- ✓ Inconsistent colors. Color printer settings and printed color change over time, depending on the conditions of the printer.
- ✓ Different colors. Same image printed from different printers appear to be different in color.
- ✓ Calibration. How frequently do I calibrate my printers? And to what standards?
- ✓ Knowledge and practice. Adjusting color settings requires experience and knowledge.
- ✓ Color Confidence. After a color calibration program has been executed for a print system, I am still unsure if it is able to reproduce the correct colors desired. There is no assurance or knowledge that it can print the right colors I want.

These resultant conflicts describe the challenges faced in color printing. Until now, there is no guarantee that the color output of a color reproduction system necessarily achieves the correct color effect. To address this challenge, Focoltone Intelligent Color Calibration System (FICCS)[1] is developed to provide a practical, repeatable and reliable solution for color print standardization. FICCS is developed based on the patented Focoltone Color System[2] and Focoltone Digital[3] ; and it brings color standardization to a practical and easily usable level by providing the methodology and the intelligence (knowledge, experience and expertise) to achieve color confidence of single and multiple printers. FICCS incorporates Artificial Intelligence (AI) techniques in its methodology. It provides a novel technique to bridge the gap between objective and subjective color comparisons through negative comparison, so as to control the variance of printed colors to an exceptionally and wonderfully low variance level.

[1] Patent pending

[2] Patent Number EP0119836

[3] Patent Numbers US5,953,990, WO97/42033, DE69707227D or EP0836556.

1. INTRODUCTION

With the rapid technological advancements in color reproduction, usage of colors in imaging and printing continues to grow at an ever-increasing pace. With the increased use of color images, the demand for high quality color printing has also increased considerably.

Color copiers, printers and professional press systems create color images by combining a small number of 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. The same CMYK image data printed using different color reproduction systems (or called color print engines) will reproduce images with different color characteristics. The different color characteristics are due to different absorption spectra of the colorants, different amounts (densities) of the colorants, and different mixing characteristics (trapping) of the colorants. The main causes of the color characteristics also include temperature changes, humidity changes, changes in paper, changes in toner/ink, usage etc.

"As color printing becomes more affordable, color adoption will continue its rapid climb," said Martin Chau, industry analyst, IDC. According to IDC research [1], currently 42 percent of personal and workgroup printers installed in businesses are color devices.

There is no printer that can reproduce color perfectly. With the emergence of open publishing systems based on standard computing platforms, color communication between different devices is getting more complex. The International Color Consortium (ICC) was established in 1993, to develop a specification for a color profile for any color device. The color profile defines a standard way for color transformation between different devices to ensure reliable color reproduction. Since the mid-1990s, a number of color management products were introduced in the market. However, none of them has achieved any real market success.

1. INTRODUCTION (cont'd)

The challenge in color printing is that there is no guarantee that the color output of a color reproduction system necessarily achieves the correct color effect. This paper addresses the challenge by presenting a practical methodology for color print standardization that enhances the concept of color management. It then introduces a system based on the methodology to make color standardization easier by means of AI techniques. Though we attempt to explain the color print standardization methodology and technology as straight forwardly as possible, this white paper is intended primarily for individuals who have a solid understanding of color management and process control within the print production workflow.

2. USE OF ARTIFICIAL INTELLIGENCE IN COLOUR STANDARDISATION

In general, color standardization is a means of ensuring that color is processed consistently throughout the entire color reproduction process. It has existed in a variety of forms since the inception of color reproduction. In a traditional color reproduction process which is a closed system operating on a CMYK basis, from image digitalization to printing, it requires that scanners, digital proofers and imagesetters are calibrated and linearised. In modern fully digital production processes with new media options, new methods for color standardization and calibration for the print engines are required. Typical color print standardization, as well as typical color control in other commercial industries, still typically utilize manual off-line color testing and manual color adjustments by skilled technicians or engineers. This process is knowledge-intensive and time-consuming. In order to understand color print standardization better, we briefly discuss the definition of color and its characteristics followed by some limitations of current ICC color management.

2.1 What is Color?

According to Webster's Revised Unabridged Dictionary [8], color (also written as "color") is defined as a property depending on the relation of light to the eye, by which individual and specific differences in the hues and tints of objects are apprehended in vision; as cool colors, warm colors etc. The sensation of color depends upon a peculiar function of the retina or optic nerve, in consequence of which rays of light produce different effects according to the length of their waves or undulations – waves of a certain length producing the sensation of red, shorter waves green, and those still shorter blue, etc. White, or ordinary, light consists of waves of various lengths so blended as to produce no effect of color, and the color of objects depends upon their power to absorb or reflect a greater or less proportion of the rays that fell upon them.

2.2 Color Characteristics

Color has physical and physiological characteristics. It can be discussed from two perspectives: objective and subjective. In the objective perspective, the phenomenon of color results from the physical interaction of light energy with an object while in the subjective perspective, color is the experience of an individual observer.

The perception of color relies on three elements: the light source, object and observer. Color is the reflection of light. Without light, there is no color. Light is essential in viewing colors. It contains the wavelengths of the electromagnetic spectrum for all colors that are visible to human eyes. Viewing under different lighting conditions will generate different perceptions of colors. Individuals would perceive colors differently even under the same condition, light source, environment; experience would also influence color perception. 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. These physical characteristics can be established using a color measurement device.

2.2 Color Characteristics (cont'd)

Color is a perception of the human eye. Color vision actually depends on the interaction of three types of cones - one especially sensitive to red light, another to green light, and a third to blue light (see Fig.1). Light rays reflected by an object, for example, a pencil, enter the eye and pass through its lens. The lens projects an inverted image of the pencil onto the retina at the back of the eye. Signals produced by rod and cone cells in the retina then start on their way into the brain through the optic nerve and reach a major relay station, the LGN (lateral geniculate nucleus). Signals about particular elements of the pencil then travel to selected areas of the primary visual cortex that curves around a deep fissure at the back of the brain. From there, signals fan out to "higher" areas of cortex that process more global aspects of the pencil such as its shape, color, or motion. Surprisingly, light rays must penetrate two layers of neurons in the retina before reaching the precious rods and cones at the back: a middle layer of bipolar cells, and a front layer of ganglion cells whose long axons (fibers that transmit electrical impulses to other neurons) form the optic nerve leading into the brain.

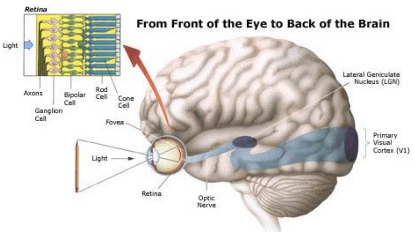


Fig.1 Illustration: Eade Creative Services, Inc./George Eade illustrator (visual system adapted from a drawing of [2]; retinal cells adapted from a drawing by Carol Donner/Tom Cardamone Associated on page 37 of [3].

A human observer sees color differently in the context of colors surrounding it. Different observers may view a same color differently in the same environment. The only way to describe colors clearly is by means of comparison. As a result, the way a particular color is perceived usually differs from the way it can be objectively measured. No matter what kind of measurement technologies used, the results should be consistent with visual assessment because the human eye is the final judge of color.

2.3 Limitations of Current ICC Color Management

The main objective of ICC is to create, promote, and encourage the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture and components. The ICC color management concept is based on device-independent color defined

2.3 Limitations of Current ICC Color Management (cont'd)

using CIE LAB or CIE XYZ for color transformation. It was established by eight industry vendors in 1993. There are two main deliverables from the consortium: ICC profile specification and Color Management Module (CMM).

Today, ICC profile and color management is a hot topic in the printing and publishing industry. But just as David McDowell, a standards consultant from a founding member of ICC, pointed out, that it is difficult to describe the role or benefits of color management for any specific user because there are so many different color reproduction workflows [9]. He also identified several key limitations of current ICC color management summarized as follows:

- Regarding CMM definition, there is insufficient data to verify that the current level of CMM compatibility will allow consistent processing of profiles by CMMs provided by different vendors.
- The ICC currently has no specifications or test procedures in place for CMMs.
- As for the reference printing conditions, CMYK output profiles require characterization data for the expected printing process.

Furthermore, ICC recommends a procedure for creation of an ICC profile for a particular printing system. But, it has not provided any method for verification of color outputs generated using the profile. These limitations are the key barriers to greater uptake of ICC color management in the printing and publishing industry.

3. FOCOLTONE INTELLIGENT COLOUR STANDARDISATION SOLUTION

3.1 Focoltone Color System

Focoltone Color System is a patented four process color (CMYK) specifying system. Focoltone Color System consists

3.1 Focoltone Color System (cont'd)

Fig.2 Focoltone Color System

of a Focoltone Color Swatch Book with 763 achievable colors in 16 sets of color charts and a color specifier chip book. It is the perfect solution for CMYK reference and CMYK calibration. Focoltone Color Library is incorporated into most design software such as Quark, Corel, Macromedia Freehand, Adobe Photoshop and Adobe Illustrator.

3.2 Focoltone Color Standardization Methodology

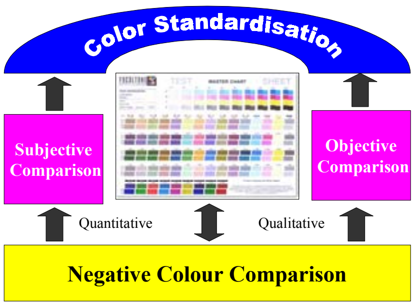


Fig. 3 Focoltone Color Standardization Methodology

This methodology is based on the patented methodology[1] for color print standardization that provides a measurable and repeatable color calibration process to guarantee color consistency on digital printers irrespective of time, place or conditions. This methodology has been further enhanced in accordance with the emergence of new technologies. The refined methodology is based on subjective and objective color comparisons of color printing. The foundation for the two color comparison methods is Negative Color Comparison. Fig.3 illustrates the foundation of the Focoltone color standardization methodology.

[1] Patent Numbers US5,953,990 and WO97/42033.

3.2.1 Negative Color Comparison

Viewing a color involves making comparison from the nature of human vision. Color comparison is a critical step in color standardization process. It is a fact that the human eye cannot measure colors accurately but can compare between colors. Two individuals looking at a single color will see it differently. 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. In a typical case, the nature of

3.2.1 Negative Color Comparison (cont'd)

the color is not important. What is important is that the difference between two colors can be seen as identical by the two individuals. Generally, there are two kinds of methods for measuring or comparing printed color with a reference color: subjective and objective color comparison.

3.2.2 Subjective Color Comparison

Subjective color comparison relies mainly on human eye to compare 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 option of an observer and may well result in disagreement between observers.

3.2.3 Objective Color Comparison

Objective color comparison always requires the use of a device to measure a color and compare with its reference. Currently such devices used for measuring the color for color standardization typically include spectrophotometer, colorimeter, densitometer, digital camera and scanner. The advantage of the objective color comparison is that it can provide reproducible data regarding the difference of two colors. The disadvantage is that the data generated may not always correlate with the way that the human eye perceives color.

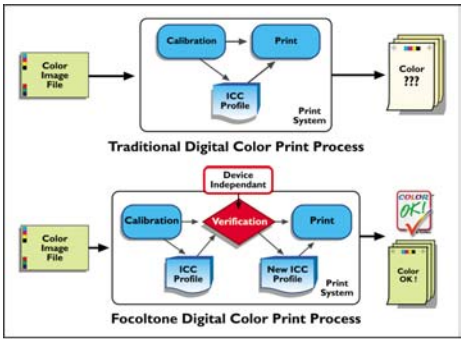


Fig. 4: Improve traditional color print process with a device independent color verification step

Focoltone color standardization methodology extends beyond traditional color calibration to include color verification (See Fig. 4). Color verification is critical for color standardization in color printing practice. Currently, some color printing system manufacturers provide their own calibration functionalities for their printing machines, but they have not provided a practical method for verifying colors after calibration of the machines. By outputting

3.2.3 Objective Color Comparison (cont'd)

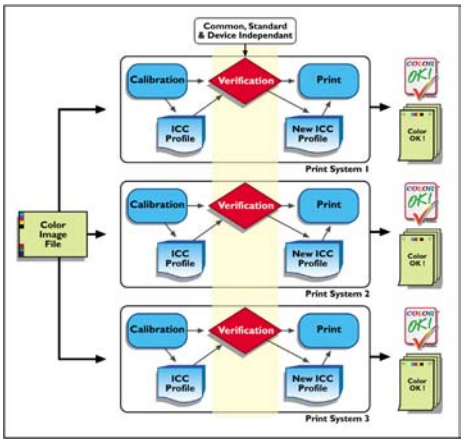


Fig. 5 An example of a common, standard and device-independent color verification procedure applied onto three different print systems to standardize their color outputs

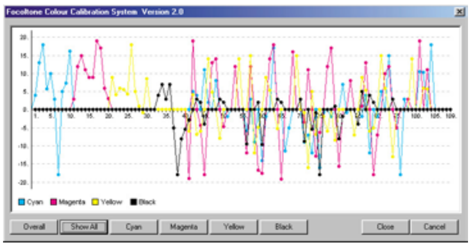
several pages of images and color patches printouts after calibration, it is still doubtful if the colors are 'correct' because these outputs are difficult to verify.

Focoltone Color Standardization methodology emphasizes color verification, which is critical for controlling the color outputs for a print system, as well as a plurality of print systems to ensure a control of their color outputs to an acceptable level. For example, Fig. 5 illustrates how to control the color quality for color printing of the same image on two different print systems. This methodology can be easily applied to a distributed printing environment to guarantee the consistency of colors outputted from different printers.

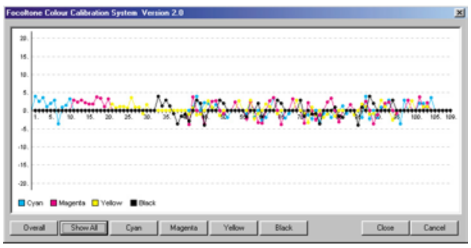
4. FOCOLTONE INTELLIGENT COLOUR CALIBRATION TECHNOLOGY

Based on Focoltone color standardization methodology, we have developed an enabling technology, Focoltone Intelligent Color Calibration System (ICCS)[2]. This technology is developed based on Artificial Intelligence (AI), it provides a novel method for comparing the printed colors against reference colors to generate color characteristics.

The generated color characteristics stored in a knowledge base, which can be presented to users in an understandable way, are useful for detecting color inconsistency in an automatic manner. It can be used as a feedback to advise an operator adjusting the color setting for a print engine in an interactive way. A sample of color characteristics is shown in Fig.7.



Before color calibration



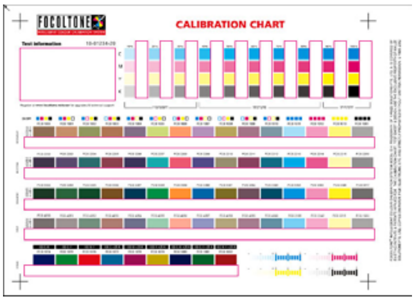
After color calibration

Fig. 7 Color shifts within an acceptable level

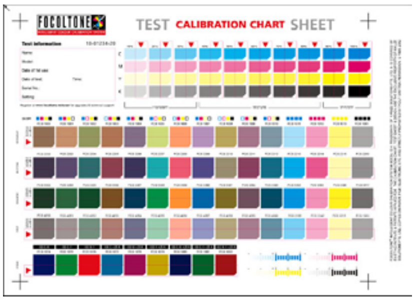
[2] Patent pending.

5. FOCOLTONE INTELLIGENT COLOUR CALIBRATION SYSTEM

Focoltone Digital Test Sheet



Focoltone Color Calibration Chart



Composite of Test Sheet and Calibration Chart for easy color comparison

A system for color print standardization has been developed with the above technology. This system can be easily customised for any colour printing devices. It will provide the following benefits:

- Maximizing the color accuracy of a printing system;
- Assuring color consistency on digital printing systems irrespective of time, place or conditions;
- Building up color confidence using a comprehensive way of verifying color;
- Reusing of knowledge and expertise.

The patented Focoltone color calibration chart comprising a series of different colour patches, is used as the base for colour comparison and verification.

6. DEPLOYMENT STRATEGY

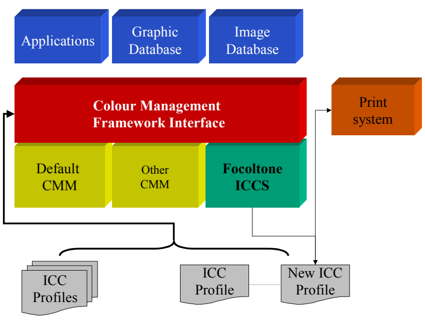


Fig.9 Architecture for deploying Focoltone ICCS for a print system

Focoltone Intelligent Color Calibration System will be deployed in various forms and in degrees of availability, scalability and growth flexibility depending on application platform options. It supports both Windows and Mac OS. The first release of the system will be available as a plug-in for Adobe Photoshop. Fig 9 shows an architecture for deploying FICCS for a print system under ICC Color Management Framework.

6. DEPLOYMENT STRATEGY (cont'd)

The Focoltone ICCS can be also be deployed in a network environment to support distributed printing. Fig.10 illustrates a deployment architecture for multiple printing systems in such an environment.

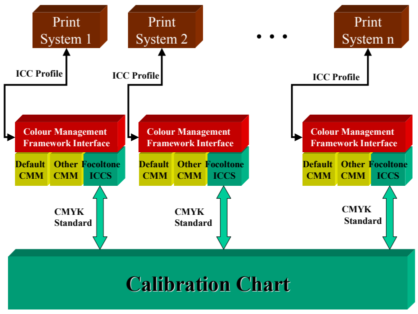


Fig. 10 Architecture for deploying Focoltone Intelligent Color Calibration System for a plurality of print systems

7. CONCLUSION

In addition to the worldwide ICC standard that provides a universal description of color profiles, many hardware and software components used in the color printing industry today offer the functions that are necessary to set up an efficient color management workflow. Working with color day by day constantly opens up new areas of application, defining new requirements for technology and application software. KiKUZE will continue to develop state-of-the-art color standardization solutions in order to ensure an ongoing improvement of basic technology and a continued optimization of the ICC Color Management Framework.

Focoltone Intelligent Color Calibration System provides a practical, repeatable and reliable methodology for calibrating not only one printing system, but also a plurality of them. It enhances the traditional color calibration method with color verification. A practical method is also presented in (Part 2 of) this paper for verifying the color outputs.

KiKUZE has developed patented technology for color print standardization through collaboration with leading Japanese, American and European researchers. This collaborative research focuses on high-speed sensing,

7. CONCLUSION (cont'd)

color measurement / comparison and intelligent color control to develop novel technologies for high quality color printing.

Future development of Focoltone ICCS will enhance current color calibration features and include new integration points with other applications. KiKUZE will continue to focus on meeting the needs of organizations for a reliable, secure and cost effective color standardization solution.

END OF PART ONE – INTRO
PART TWO comprises of technical info on the methodology and system. Patent pending.

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