# Screen's Color Management System for the Graphic Arts Industry


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## Abstract

Dainippon Screen's Color Management System (SCMS) is currently under development for use with device-dependent CMYK-based equipment, and RGB-based devices. SCMS will provide color space transformation or linkage to the CIE 1976 $L^*a^*b^*$ color space. The SCMS concept is based on Screen's CMYK image data formats. The SCMS was announced two years ago at IGAS '93 where many attendees viewed this new Screen approach to color management technology.

At DRUPA '95, the SCMS concept for handling RGB-based devices and the transformation of color data between CMYK and RGB-based devices, will be revealed and explained, and this disclosure will be in conjunction with the introduction of products using this CMS technology.

Before the full introduction of SCMS at DRUPA '95, this paper reveals the technical characteristics of the color management system as follows: (1) As precise as possible color data acquisition and measurement are carried out. (2) As precise as possible and as flexible as possible device modeling is carried out (3) As precise a transformation as possible, which is as quick to calculate as possible, is carried out. (4) A different algorithm is used in the case of color matching on the colorimetric measurement, especially on display of creative work by designers.



**Keywords**: Screen, color management, device-dependent, RGB, CMYK, link, colorimetric, transformation, color space, color gamut


## 1 Introduction

As prepress systems become more open and interface easily to other systems, more production is accomplished by using networks, and the work given to operators is divided

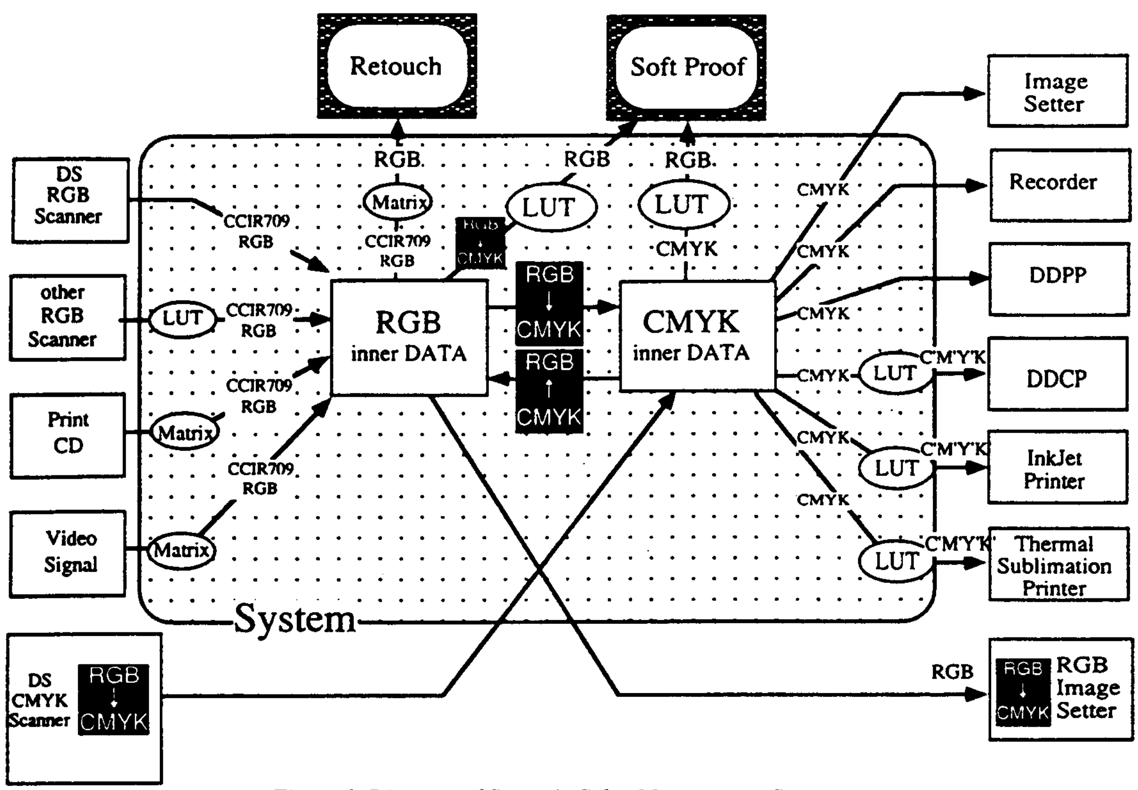


*Figure 1. Diagram of Screen's Color Management System*

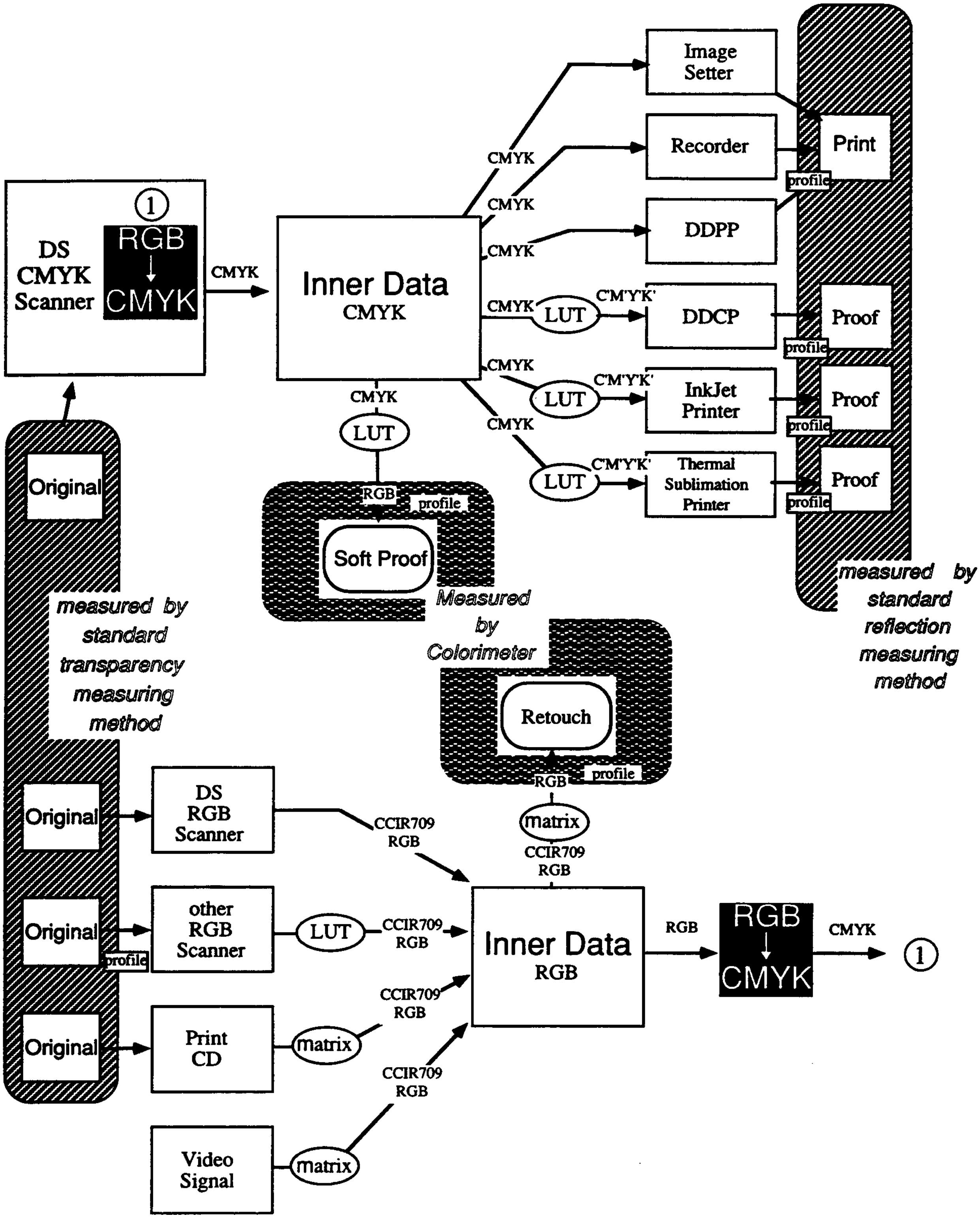


*Figure 2. Screen's Future Color Management System*

into smaller pieces or page elements. To achieve efficient production workflow it is necessary for prepress operators to be able to perform the same processing tasks or operations in a comparable way at any given time.

On the other hand, color retouching in prepress work is performed to achieve colors that meet the desires of clients.

We believe the SCMS system must cope with the two production issues mentioned above which externally appear to be in contradiction to each other, and thus it is necessary for our color management system to provide the appropriate color production tools. Therefore, different algorithms are used for different production tasks in our color management system, even on the same device.

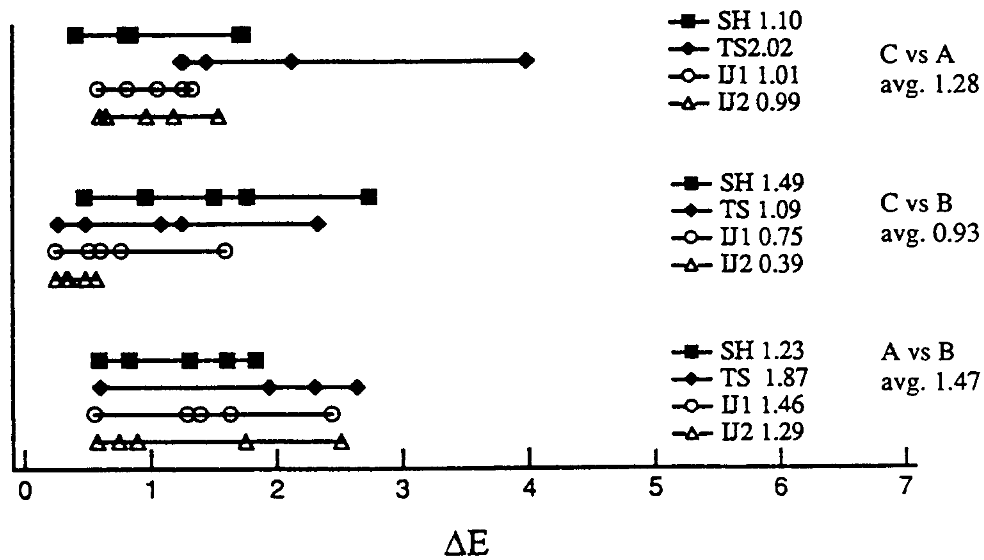


*Figure 3. Color difference measured by different devices using the same patches*

Became the Screen CMS is based on colorimetric data which has been previously measured, it is very important to do such measurement in accordance with the international standards provided by the ISO. This assures reproducibility of the color measurement by measuring equipment.

Screen is now developing a color management system that considers these color prepress production requirements. This paper presents both the concepts and techniques of our color management system which are necessary to carry out the individual CMS tasks to provide the best color rendering solutions.

## 2 The Concept of Screen's Color Management System

To manage color is not a new concept in the workflow of graphic arts prepress production. Even in the past when scanners, and recorders were integrated systems, color originals were faithfully printed without are of any other specific CMS techniques, and scanners fully controlled and rendered the desired colors. In other words, device-independent color was preceded by proprietary systems that provided dosed-loop high quality color management and imaging solutions.

There should be an introduction here, such as the SCMS basic concepts are:

1. A color management system should provide high quality color reproduction like that performed by high end color scanners equipped with color computers.
2. Transformation of color data must retain all necessary colorimetric information to allow high quality printing.
3. The color management system must not reduce productivity.

The Screen CMS is divided into three components (these also could be sections, modules, or elements). These are the RGB based component (which mainly has to do with data input), the CMYK-based component (providing the function of data output), and the middle CMS component which links together the input/output elements mentioned above (and performs transformation from RGB to CMYK and vice versa). Please refer to Figure 1. The following explains the component parts of the SCMS as follows:

### 2.1 The RGB-Based Component (Data Input)

This SCMS component is used to input the color data and digitally retouch it. Layout artists and designers art able to freely use their imagination in this first production step, and then preview the results on a monitor or printer to simulate the final printed piece. They often use RGB images, usually supplied via CD-ROM picture libraries, M a part of their page makeup designs. Because images supplied on many CD-Rooms are captured and stored in RGB color space, they are easier to handle, even if they are to be converted into the CMYK data for final printing.

We have decided that the standard RGB color space to be used in the SCMS should be CCIR 709. All RGB-based data should be converted into this standard color space whenever a transformation in the RGB-based component is carried out. The merits of adopting CCIR 709 as our standard color space are as follows:

1. It reduces the computational burden when images are transformed, especially into the color spaces of monitors.
2. ANSI IT8.7/4 supports this standard.
3. The images supplied by many CD-ROM vendors can be easily transformed using CCIR 709.

The characteristics of the RGB-based component are described below:

1. Matching colors contained in the colorimetric data is rigorously carried out in this SCMS component be cause it is separated from the linkage component (RGB/ CMYK transformation).
2. The RGB-based images acquired by Screen scanners are more easily used in other popular color management systems which have adopted CCIR 709 standard.
3. RGB-based images acquired by scanners manufactured by other vendors are also more easily input into the Screen CMS.

### 2.2 The CMYK-Based Component (Data Output)

The CMYK-based component is used to output proofs, or print image data. It is most important to simulate the final process color printed results by using the digital data at as early a step as possible to assure the same colors of the original images are printed on all the devices within the desired gamut, if possible. We do color matching colorimetrically based on the CIE 1976 L*a*b* , and in practice do it by use of look-up tables generated from the measured data acquired via the SCMS RGB-based component. A color target, developed by the ANSI group, IT8.7/3 (which contains 928 color patches) is effective for color matching, but it lacks color patches which can be used to control the neutral color balance. We will add appropriate neutral patches, if necessary, to the IT8.7/3 color target.

Screen has also develops and sells a color proofer that does not have a color computer to perform color transformation. This device, such as TC-P1080, employs the same ink, paper and dot formation as are need in process color printing, and does not use CMS software to match colors. We think that color proofing is a fundamental color matching tool to match the colors in digital data process color printing output. This color matching is possible because the color gamut of the Screen proofer is the same as that of the printing process. The merits of CMYK output component are described below:

1. Basically, color matching is done based on the colorimetrically measured data within the color gamut, and that out of gamut, this is done via gamut compression along the L*, a* or b* axis.
2. The purpose of this SCMS CMYK output component is to match the digital image data colors with those of conventional process color printing. The SWOP color target from U.S., and a new Japanese color target (now being developed), and the local color targets developed and provided by private companies, are and will be adopted as standard color targets for color space transformations.
3. In the future, Screen will provide customers with a maintenance service to calibrate their devices and to match their color output to the process colors they specify.

How to transform out of gamut color with consideration of human color perception, is now being developed.

### 2.3 The Linkage Component (Data Transformation from RGB to CMYK and Vice Versa)

This SCMS component is used to transform RGB-based data to CMYK-based data, and vice versa. It is based on the colors designers desire to achieve on output, rather than the colorimetrically measured data. This SCMS component provides for high duality process color output. High quality color transformation is one of Screen's traditional and significant techniques that have been developed over the years in our proprietary color prepress systems. We have extracted transformation functions from our scanner systems by replacing this hardware with the equivalent in software. Screen is now providing customers with this software in various software configuration, one package being ColorScope. This enables us to separate prepress devices for data input and data output conceptually and to develop and improve each module (RGB-based and CMYK-based components) independently.

Figure 2 shows a complete block diagram of the future Screen CMS.

## 3 The Characteristics of Screen's Color Management System

There are several situations where the SCMS neither can, nor should be applied, they are as follows:

1. The SCMS should not be used with color devices that are unstable.
2. It should not be used with a color target that is not calibrated (the color patches of the target have not been colorimetrically measured).
3. It should not be used to transform color data except where process color printing is to be carried out.

We assume that the situations mentioned above can not be solved with only color management techniques, and thus these situations should be excluded.

The characteristics of the SCMS are described below:

1. As precise as possible color data acquisition and measurement are carried out.

Our CMS is based on the colorimetric data collected by a precise method of measurement. It is well known that different measurement techniques (for example: different optical geometry, the spectra of the light source employed, or the chromaticity of the white point employed for calibration) can generate or cause incorrect or undesirable measurement values. We measure sets of color patches in accordance with ISO/IEC 13655 (or CGATS.5), and the white plate used for calibration is carefully stored to insure its chromaticity is unchanged.

Figure 3 shows the color difference of the color patches measured by each type of measuring equipment in accordance with ISO/IEC 13655. This shows that all the colors can be matched (or controlled) within 2 $\Delta$ E.

Figures 4 to 7 show the spectral difference of the color patches measured by each type of equipment in accordance with ISO/IEC 13655. These patches were imaged by different printing technologies: dye thermal sublimation (TS), inkjet (IJ), and silver halide (SH). Two kinds of paper were employed by the inkjet printer, glossy (IJ1), and the manufacturer's default paper (IJ2). The measured results support the facts mentioned above. We think that it is a trivial difference because positive color film duplicates can usually be controlled within 3 $\Delta$ E.

2. As precise as possible and flexible as possible device modeling is carried out.

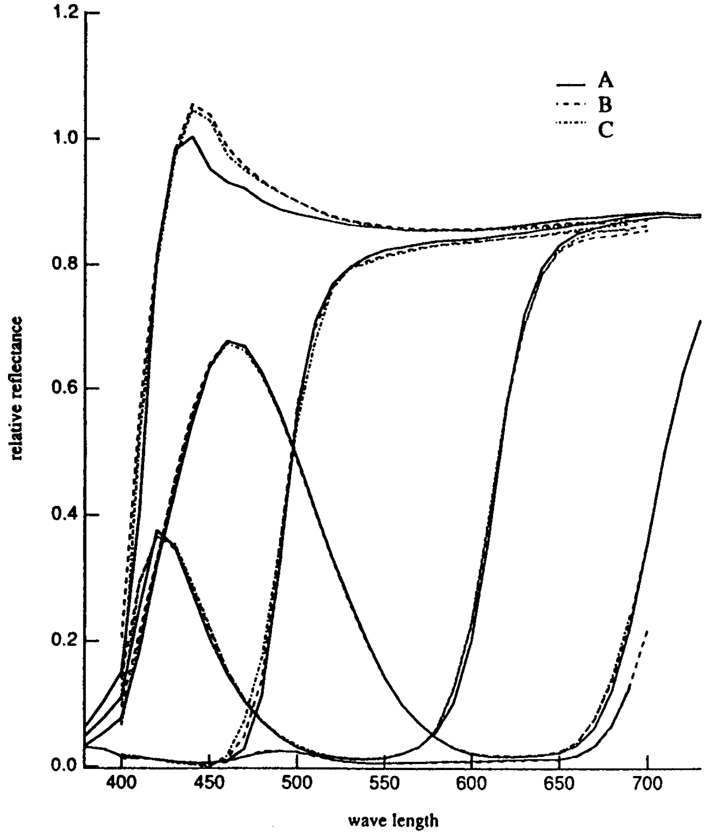


*Figure 4. Spectral data differences measured by different measuring equipment* [*Thermal Sublimation*] *(A,B,C).*

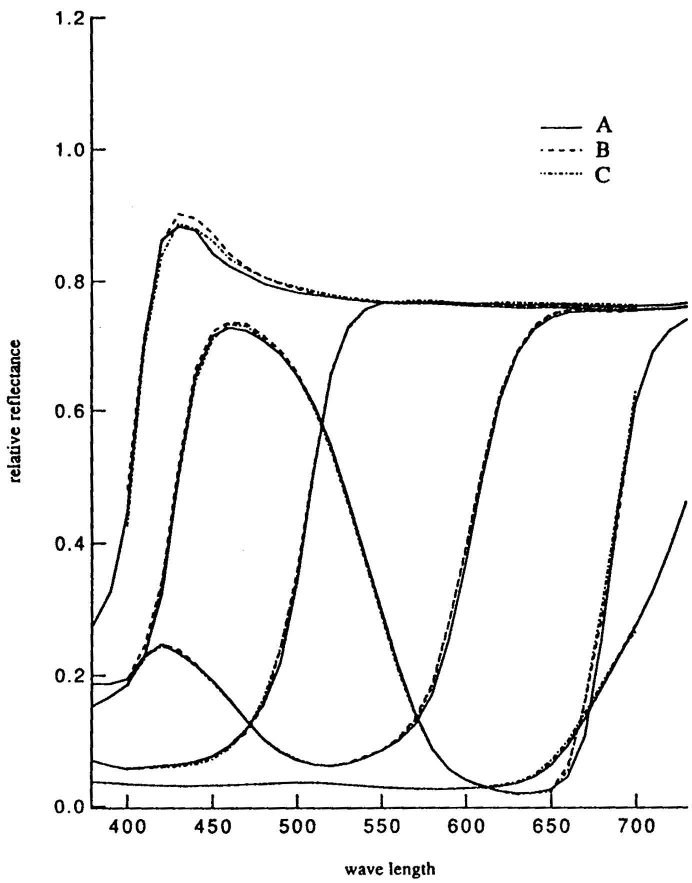


*Figure 5. Spectral data differences measured by different measuring equipment* [*Ink Jet, normal paper*] *(A,B,C).*

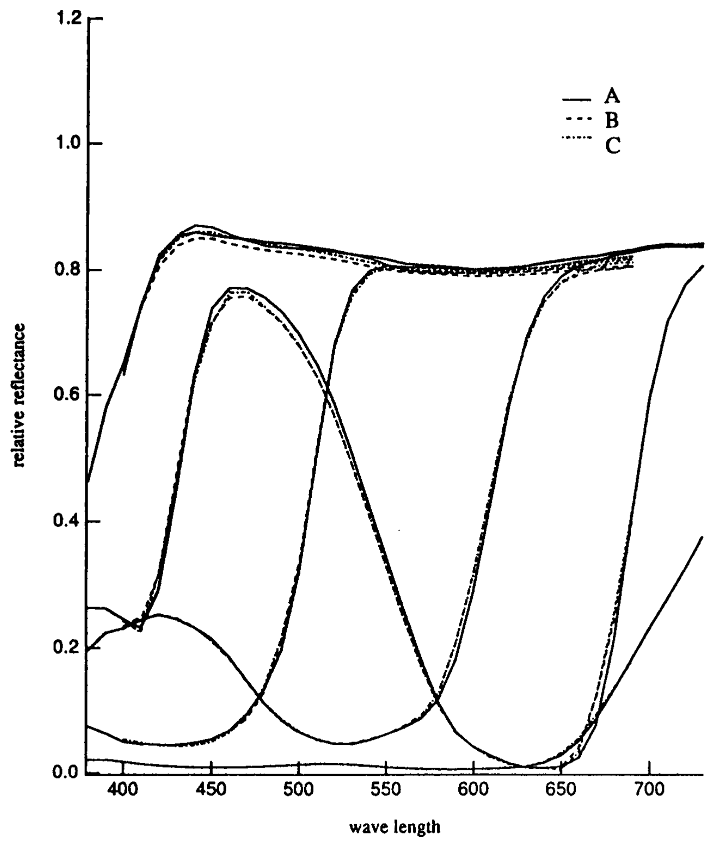


*Figure 6. Spectral data differences measured by different measuring equipment [Ink Jet, glossy] (A,B,C).*

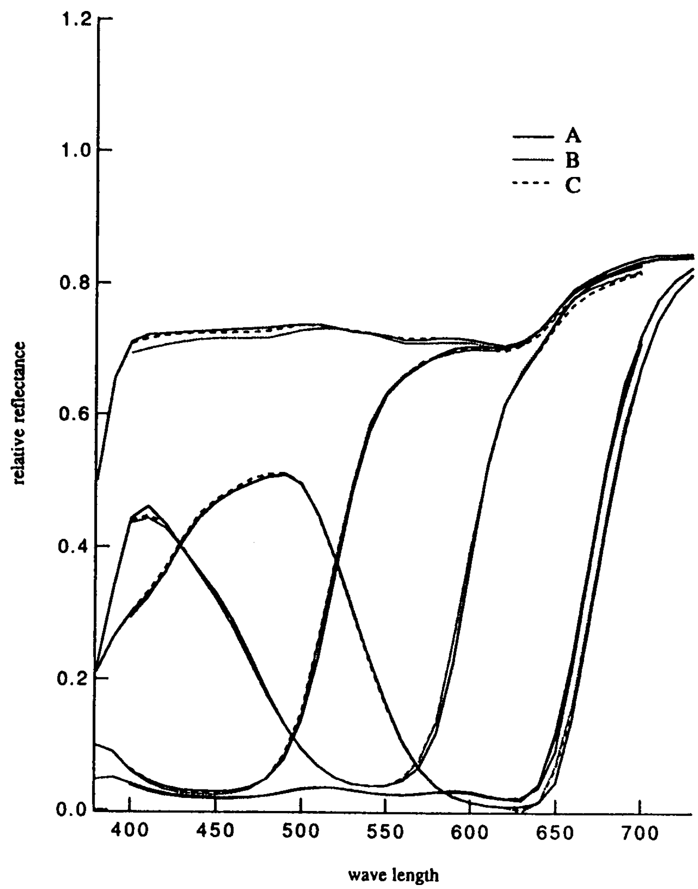


*Figure 7. Spectral data differences measured by different measuring equipment [Silver Halide] (A,B,C).*

In the prepress industry, there are many kinds of input and output devices available. For input, for example, we have color scanners, digital cameras, etc. For output, there are scanning devices such as imagesetters, proofers, and many kinds of printers (inkjet, dye thermal sublimation, and so on). The SCMS applies the same color modeling to these devices, although the complexity of each applied model is different based on the unique characteristics of the device.

Figures 8 and 9 show how to select the comet number of patches and their values that are the most appropriate for making up the most precise and uncomplicated device color model. In view of all the device-dependent RGB or CMYK-based color spaces, the CIE 1976 L*a*b* color space is significantly distorted and its converse is also true. As the colors employed in each image are different, such selection has much influence on the transformed results. To start with, we are using the U.S. printing industry SWOP color target, and a new Japanese color target (that is being developed) to do general transformations, which rue common to many natural color images. After the general transformation, a minute adjustment is made for every image, if necessary, based on the customers requirements. Besides, matching colors based on the printed output, in the future, Screen customers will be able to get a color calibration service for our devices.

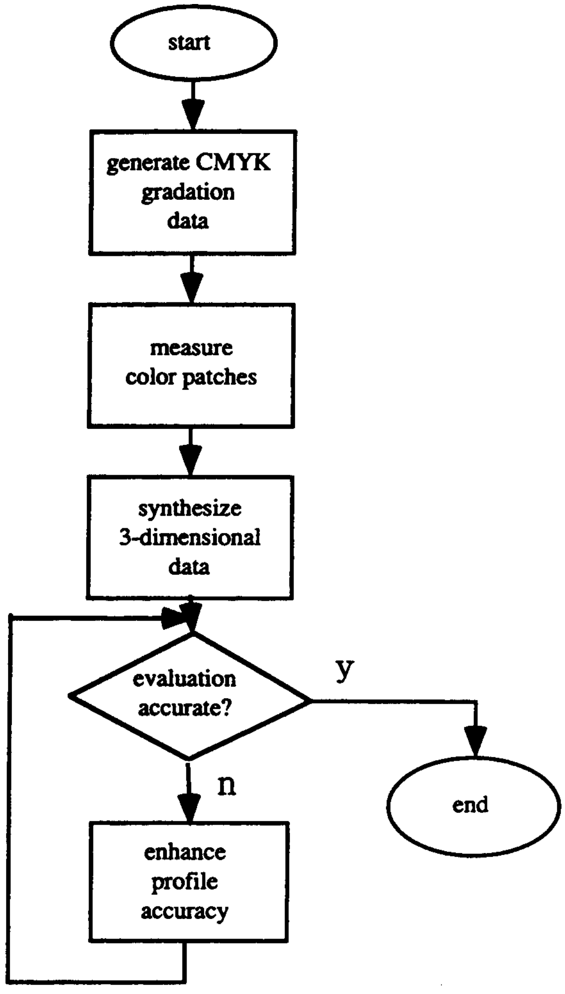


*Figure 8. Flow chart to determine the sample points.*

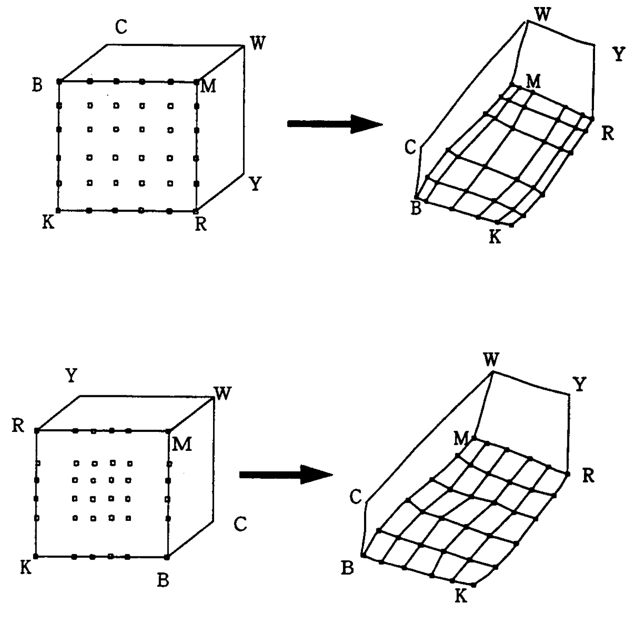


*Figure 9. Method to select the sample points to be measured.*

3. As precise a transformation as possible, which is also as quick to calculate as possible, is carried out.

Approximating the color transformation by a set of higher order polynomials, and interpolating linearly between the colorimetric data within the cube, which is a part of the color gamut, to generate the device independent data from the device-dependent and vice versa are utilized.

This linear interpolation within a cube is already implemented in Screen products, and is based on patents granted in many countries such as Japan, U.S., U.K. and Germany. Figure 10 shows the schematic explanation of our patents and how to divide the color gamut for a device. The linear interpolation is done after each cube is divided into 6 tetrahedrons. This is an extension of triangulation in two dimensions to three dimensions. Within each tetrahedron, the corresponding values are calculated by a single linear formula. Owing to significant distortion of the color gamut, relative to another color space, to promote mote precise color matching, results in the greater number of the color patches to be measured or contriving a new method of interpolation. However, in practice the patches to be measured art very limited in number. The Screen patent enables us to interpolate linearly in a cube which is divided by the sample points. In other words, the color patches measured are very effective in controlling the grey balance. Because humans are very sensitive to grey color, this technique assures sufficient accuracy and speed of transformation, and consequently limits the error of the measured scan data.

4. A different algorithm is used in the case of color matching for colorimetric measured data, especially for viewing of creative work prepared by designers.

Color prepress equipment users, such as designers, have many reasons to display and print digital data, and some of these soft and hard copy renderings or presentations do not require device-independent color.

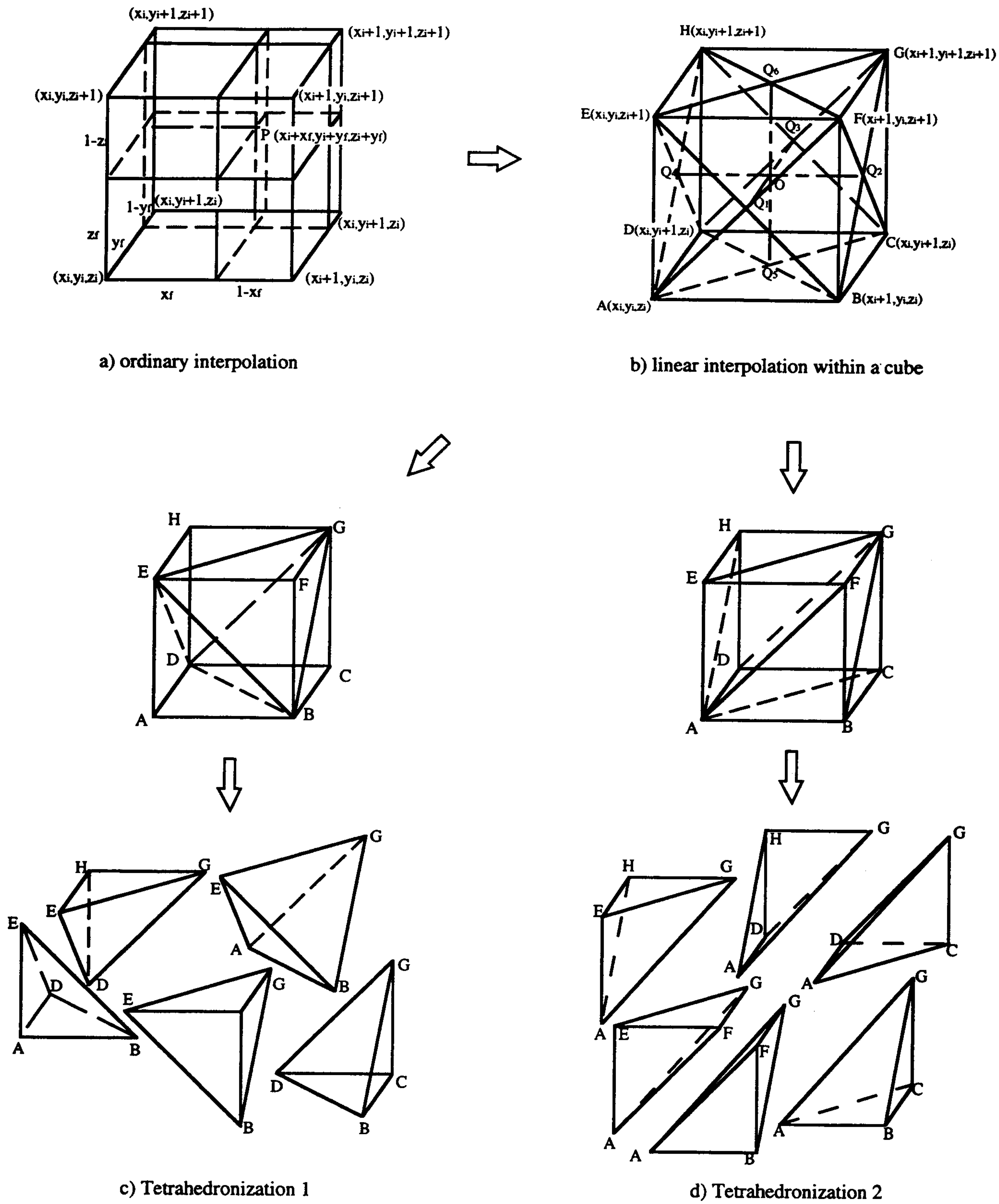


*Figure 10. Linear interpolation within the color gamut cube.*

This is especially true for color display monitors, many designers like to freely use their imagination, and they consider the gamut compression caused by the mapping performed during color transformation to a standard color system, as too degrading to their work. So different and appropriate algorithms are used to accommodate these requirements, particularly in the case of color display monitors. In the RGB-based component of the SCMS, a good example of this is a display monitor which is used for color design work, and is often used to provide a rough approximation of the results of early production steps.

## 4 Screen's Color Management System in the Future

We believe the SCMS will be improved by adding the color management techniques mentioned below:

1. To provide a CMS customizing service at the request of our customers.

We think that it is important to calibrate the user's devices and to provide custom color matching as well as to standardize, because it make CMS upgrades more convenient. Such a service is scheduled in the future, similar to maintenance services available for computer systems.

2. To develop a new method of gamut mapping based on human color perception.

Because color depends on the human visual senses, and out of gamut color can not be displayed or printed, that is exactly, a new method for gamut mapping is needed. In other words, in the future a method that corresponds to each device's color gamut will be developed, and this will be based on the human psychological process of color recognition.

## 5 Conclusion

As explained in the previous sections, Screen is currently developing a color management system which copes with the two production issues which externally appear to be in contradiction to each other as follows:

1. To render the desired colors of clients.
2. To realize the device-independent colors.

Then, the Screen CMS has the characteristics mentioned below:

1. As precise as possible color data acquisition and measurement are carried out.
2. As precise as possible and as flexible as possible device modeling is carried out.
3. As precise a transformation as possible, which is as quick to calculate as possible, is carried out.
4. A different algorithm is used in the case of color matching on the colorimetric measurement.

In other words, this means that the device-independent color is not always the best solution for the graphic arts industry for the present and this SCMS also provides the high quality color transformation solutions need in our proprietary system.

In the end, we present the results of this SCMS to you at DRUPA '95, and believe its excellence can be proved by your eyes.

## 6 Acknowledgments

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