

Standard High Precision Pictures : SHIPP

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Abstract

Along with the recent rapid penetration of personal computer, internet, digital camera, etc., full color images have become widely handled in digital form by various classes of users. In such a trend, technologies for color management system (CMS), printing, hardcopy output, image transmission, image compression, etc. are highlighted, and their refinements are on way to achieve higher image qualities.

In the research activities in image technologies, the significance of high precision standard pictures is self-evident as they facilitate the evaluation of image processing algorithm, the accurate comparison of image output devices, etc.

In April 1997, the activity of the Committee for Standard High Precision Pictures (Note 1) has resulted in the preparation of high resolution standard pictures characterized by that they are expressed by 16bit XYZ data as well as 8bit CIELAB data and Calibrated RGB data.

The set of pictures named SHIPP consists of four full color natural scenes and a computer-generated chart, each expressed in three color spaces, i.e., XYZ, CIELAB, and Calibrated RGB. A detailed description of the last color space will be given later. The image data are formated according to TIFF6.0 and recorded in a CD-ROM.

Objectives and Background

An example of standard color image data is given by ISO/JIS-SCID (Standard Color Image Data (Note 2)). This is the first standard in the form of digital data commonly applicable to any output devices, and is now widely used in the technical fields of printing, hardcopy, image transmission and compression, etc.

However, there are a few problems with SCID. Since it originated in the commercial printing industries, its image data is described in terms of the dot coverages in CMYK, which makes it difficult to accurately define colors when the data are to be used in image media other than conventional printing. Moreover, the data depth is limited to 8-bits/channel, thus sometimes causing noticeable quantization errors during various types of image processing.

In order to solve these problems, the Committee for Standard High Precision Pictures started its activity to prepare a set of standard pictures with the following characteristics:

1). Device-independent XYZ/CIELAB values,
2). Image data of 2 bytes/channel, and
3). Image resolution of 4096 x 3072.

The activity resulted in the development of a set of full color pictures named SHIPP satisfying the above aims in April 1997.

SHIPP is expected to meet well the today's requirements in the various technical fields such as the color gamut evaluation of imaging systems, the image quality evaluation of image output devices, the estimation of the degree of quality deterioration accompanied by image data compression, etc.

Full Color Natural Scenes and Color Chart Comprising SHIPP

Table 1 depicts the specifications of the image data for full color natural scenes and for the color chart composing SHIPP.

In choosing these scenes, the 8 scenes of SCID were referred to from the viewpoint of significant attributes for subjective evaluation. The present four scenes include those attributes in a well-balanced manner.

The 4 x 5 inches color transparencies which record the four scenes were scanned with a high precision scanner. The SHIPP-XYZ data were processed to obtain the XYZ tristimulus values of each pixel. The XYZ tristimulus values were then converted to those for SHIPP- CIELAB data, and SHIPP- Calibrated RGB data, respectively.

The color chart has two zones, the first consisting of 6^3 color patches with systematically changing RGB values, and the second consisting of 11step color wedges in red, green, blue, cyan, magenta, yellow and gray.

Definition of Color Space

The video RGB data (digitized video voltage expressed in RGB) are the most simple, since they can be directly displayed on color monitors without any conversion. How-

Table 1. Specifications of SHIPP

No.	Nick-name	Pixels (Width x Height)	Color Space	Data Volume (Mbytes)	Main Subjects	Evaluation Objects
P1	Bride	3072 x 4096	XYZ	75.5	Close-up portrait	Tone reproduction of flesh
			CIELAB/ Calibrated RGB	37.7		
P2	Harbor	4096 x 3072	XYZ	75.5	Fine, regular structures	Image processing technique
			CIELAB/ Calibrated RGB	37.7		
P3	Wool	4096 x 3072	XYZ	75.5	Highly saturated, colored products	Color reproduction
			CIELAB/ Calibrated RGB	37.7		
P4	Bottles	3072 x 4096	XYZ	75.5	Lustrous metal products	Reproduction of gray
			CIELAB/ Calibrated RGB	37.7		
C1	Chart	2736 x 1332	XYZ	21.8	Color patches	Color reproduction
			CIELAB/ Calibrated RGB	10.9		

ever, because of their device-dependency, it is necessary to relate them with the device-independent color coordinates.

The only standard in practical use defining the conversion from XYZ tristimulus values to video RGB values is ITU-R BT.709[1)]. This standard is now widely used for the setup of electronic image capturing devices such as broadcasting video cameras. ITU-R BT.709 is based on clearly defined tone reproduction (opto-electronic transfer) characteristics, color primaries and white point (color temperature). Thanks to the standard, the mutual conversion between XYZ tristimulus values and video (i.e. Calibrated) RGB values is possible.

The readers should refer to Appendix 1 as for the properties of sRGB.

Definition of the Color Space for Calibrated RGB

The Committee adopted ITU-R BT.709 as the premise of defining Calibrated RGB color space, taking into account the wide acceptance as a defacto standard. ITU-R BT.709 is specified as follows;

(i). The color temperature of the white point: D65.

(ii). The color coordinates of the primaries:

red	x = 0.6400, y = 0.3300
green	x = 0.3000, y = 0.6000
blue	x = 0.1500, y = 0.0600

From (i) and (ii), the conversion matrix combining XYZ tristimulus values (D65) with linear RGB is given by

$$A = \begin{bmatrix} 3.2410 & -1.5374 & -0.4956 \\ -0.9692 & 1.8760 & 0.0416 \\ 0.0556 & -0.2040 & 1.0570 \end{bmatrix} \quad (1)$$

(iii). Opto-electronic transfer characteristics:

$$V' = \begin{cases} 1.099V^{0.45} - 0.099 & \cdots (0.018 \le V \le 1.0) \\ 4.50V & \cdots (0.0 \le V < 0.018) \end{cases} \quad (2)$$

V' : the nonlinear RGB values.(the video RGB values)
V : the linear RGB values of scenes.

The above specifications are summarized as follows; the Calibrated RGB values are obtained by the opto-electronic transformation defined by (iii) of the values needed for the colorimetric reproduction of scenes illuminated by a D65 light source by using the primaries defined by (ii).

Definitions of the Color Spaces for XYZ and CIELAB

Alternatively, the relationship between XYZ tristimulus values and Calibrated RGB values is elucidated as follows; the colors expressed in terms of XYZ tristimulus values forming a scene under D65 illumination are precisely reproduced when these XYZ tristimulus values are encoded by ITU-R BT.709 to give the corresponding non-linear RGB values and when they are displayed on a monitor having the D65 white point, based on the 709 primaries, and provided with the inverse characteristics of the 709 opto-electronic transfer characteristics. It should be noted, however, the precise reproduction here implies the colors on the monitor have the same XYZ tristimulus values as the original scene, not guaranteeing the matching of color appearance.

SHIPP-XYZ data are regarded as the expression of scenes under D65 illumination. As it is almost impractical to carry out colorimetric measurements on real scenes, SHIPP takes the position to regard the color data recorded with the color reversal photographic film as first approximations of those of the original scene.

SHIPP- CIELAB data can be derived by use of the following equations with these XYZ tristimulus values:

$$\begin{aligned} L^* &= 116\, f(Y/Y_0) - 16 \\ a^* &= 500\{f(X/X_0) - f(Y/Y_0)\} \\ b^* &= 200\{f(Y/Y_0) - f(Z/Z_0)\} \end{aligned} \quad (3)$$

$$f(P/P_0) = \begin{cases} (P/P_0)^{1/3} \cdots\cdots\cdots P/P_0 > 0.008856 \\ 7.787(P/P_0) + 16/116 \cdots P/P_0 \le 0.008856 \end{cases}$$

where X_0, Y_0, Z_0 is the XYZ tristimulus values of white point, P is X ,Y ,Z, and P_0 is X_0, Y_0, Z_0.

Preparation of Standard Pictures

SHIPP-XYZ Data Preparation

The workflow of data preparation (calculation) in the natural scenes for SHIPP is shown in Fig. 1.

Aesthetically surpassing color transparencies with fine compositions as well as well-balanced color schemes satisfying the present needs in 4 x 5 inch size were taken with Fujichrome RDP2. They were scanned with a high precision scanner specially modified to meet the present requirements to obtain 12bits/channel density data. Main specifications of the scanner used are summarized in Table 2.

Table 2. Specifications of the Scanner

Manufacturer, Product Name	Dainippon Screen Co., SG-1000(modified)
Scanning Aperture	25 microns square
Density Resolution	0.001 at D < 2.5
A/D Conversion	Analog signals in Density were quantized to 12bits/channel.

By the inverse transform of the film gamma, the acquired density data are converted to integral densities which are proportional to the logarithm of the scene luminance. Then, they are converted to analytical densities, and further to spectral transmission distribution. More detailed descriptions of these procedures are found in References 2 and 3.

By combining the spectral transmission distribution of each pixel thus obtained with the data for D65 CIE standard light source [JIS Z8720] and the color matching functions in XYZ color space for 2 degree viewing field [JIS Z8701], one obtains XYZ tristimulus values.

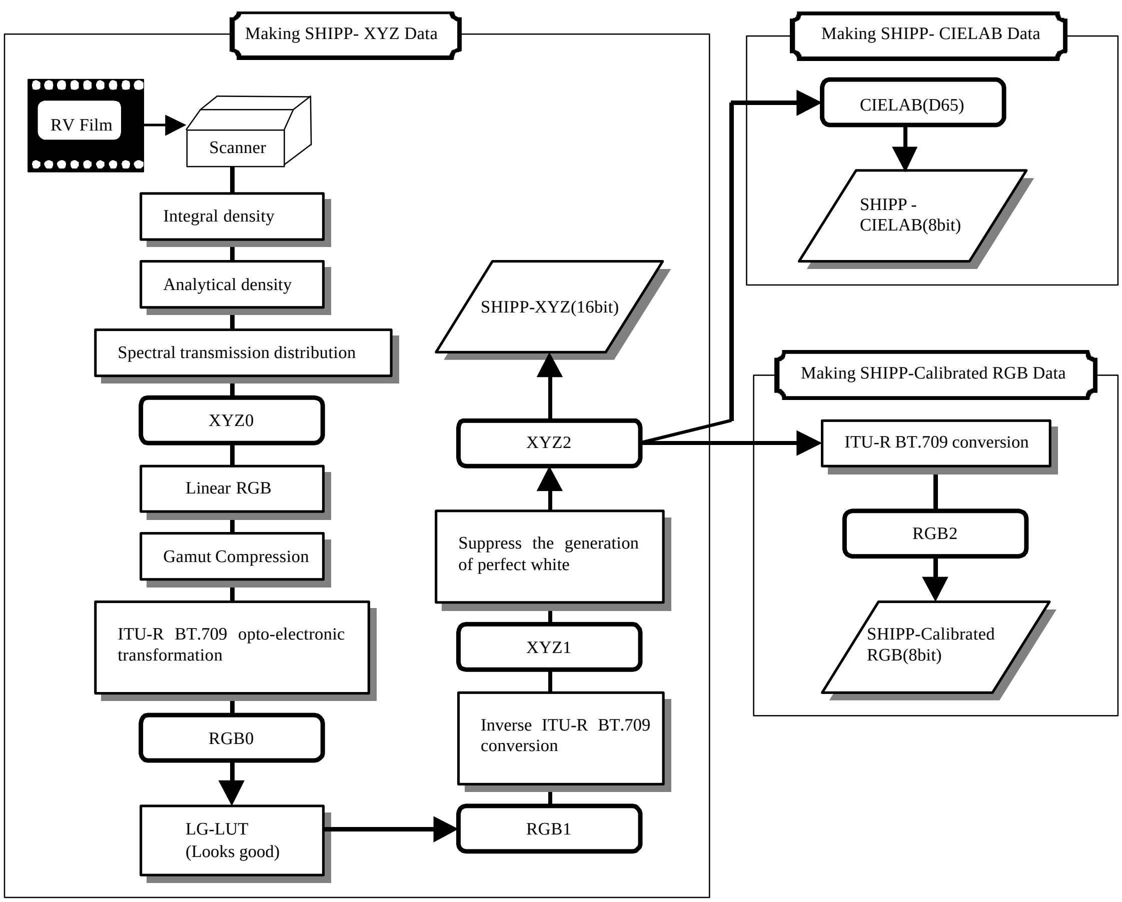

Figure 1. The workflow of data preparation in the natural scenes for SHIPP

Original Scene Optimization

Pictures used as standard must be judged good or pleasing on the monitor (including sRGB monitor[4]) as well as in the form of hardcopy (Appendix 2). It must be also kept in mind how to manage data that might fall outside the color gamut through the conversion from XYZ_0 values to Calibrated RGB.

By taking into account these factors, the workflow in the SHIPP operation includes a checking step of temporary data conversion into the monitor color space as is shown in Fig.1.

In the workflow, outside-the-gamut data which generate at the calculation of Calibrated RGB are dealt with in such a manner that the non-linear RGB values become always positive by expanding the tonal range at the conversion of linear RGB to non-linear.

Unfortunately, two problems arise at this procedure.

By multiplying Looks Good (LG-) LUT in RGB color space, there arises a possibility of XYZ_1 becoming perfect white under D65. In such a case, the picture may well be judged unpleasant, containing the so-called white points in printing industries.

Another problem is associated with data handling; to maintain accuracy, all the data are calculated in double precision throughout the workflow. But, matrices A and A^{-1} have been defined down to four places of decimals (See Appendix 3). Then, their product may not result in unit matrix, then causing RGB_2 values exceeding the range of 0.0 ~ 1.0 though the corresponding RGB_1 values lie between 0.0 and 1.0.

To solve these problems, we compressed the XYZ tristimulus values near 1.0 at the conversion of RGB_1 to XYZ_1 to suppress the generation of perfect white. Furthermore, negative values were subjected to gamut compression, while those above 1.0 to a newly explored white data compression technique.

As the perfect solution was still difficult, pictures satisfying the following conditions as much as possible were selected.

1. Pictures looking good both on monitors and as reflection prints.
2. Pictures with minimum data overflow and underflow

SHIPP-XYZ Data

SHIPP-XYZ data are named X_{16bit}, Y_{16bit} and Z_{16bit}, and defined as XYZ tristimulus values multiplied by 600. They are unsigned and rounded to the nearest integers.

$$\begin{aligned} X_{16bit} &= 600.0 \times X \\ Y_{16bit} &= 600.0 \times Y \\ Z_{16bit} &= 600.0 \times Z \end{aligned} \quad (4)$$

SHIPP-CIELAB Data

Among SHIPP-CIELAB data, L^*_{8bit} data are defined as L* multiplied by 2.55. They are unsigned. On the other hand, a^*_{8bit} and b^*_{8bit} data are signed integers rounded from a* and b*.

SHIPP-Calibrated RGB Data

According to ITU-R BT.709, as XYZ tristimulus values are converted to linear RGB values.

$$\begin{bmatrix} R_{709} \\ G_{709} \\ B_{709} \end{bmatrix} = A \begin{bmatrix} X/100.0 \\ Y/100.0 \\ Z/100.0 \end{bmatrix} \quad (5)$$

Then, linear RGB are converted to non-linear RGB via the ITU-R BT.709 opto-electronic transformation

$$V_{709}' = \begin{cases} 1.099 V_{709}^{0.45} \quad 0.099 \cdots (0.018 \le V_{709} \le 1.0) \\ 4.50 V_{709} \quad \cdots (0.0 \le V_{709} < 0.018) \end{cases} \quad (6)$$

V_{709}': the nonlinear RGB values.(the video RGB values)
V_{709} : the linear RGB values of scenes.

SHIPP-Calibrated RGB data, R_{8bit}, G_{8bit} and B_{8bit}, are defined as R_{709}', G_{709}' and B_{709}' data each multiplied by 255. They are unsigned and rounded to the nearest integers.

$$\begin{aligned} R_{8bit} &= 255.0 \times R_{709}' \\ G_{8bit} &= 255.0 \times G_{709}' \\ B_{8bit} &= 255.0 \times B_{709}' \end{aligned} \quad (7)$$

SHIPP Pictures as Subjective Quality Evaluation Tool

Though, for experts in imaging technologies, it is almost unnecessary to explain how to use each picture composing SHIPP, the following descriptions are given only as a short guide to how to make an effective use of SHIPP.

Harbor

The thin wires stretching sails, the raw of houses with windows, and the roofs with fine structures are all suited for the evaluation of image sharpness. The blue sky area on top can be used for the check of tone jump. Objects with fine structure can also be used to evaluate the registration accuracy of output devices, image deterioration owing to data compression, the existence of jaggies, etc.

Wool

This scene is designed for the evaluation of color gamut of devices. All the elements composing the scene including the woolen yarn, the color pencils, the ribbons are highly saturated at various lightness levels, sometimes exceeding the gamut of a system in concern

Bride

Self-evidently this scene is for the evaluation of skin tone particularly in highlights and shadows. The favorable reproduction of the veil requires a delicate highlight tone, and the hair demands high resolution together with an ample shadow gradation.

Bottles

This scene is suited for the evaluation of tone reproduction of grays as well as of reproduction of lustrous appearances of metallic objects. The grading backdrop can be used to check color balances at almost neutral areas, and to optimize the reproduction of grays. Conditions for a favorable reproduction of the reflection at metal surfaces and of fruits can also be explored.

Summary

The Committee for Standard High Precision Pictures which was organized to prepare high resolution standard pictures succeeded in achieving its object in April 1997. The resulting set of pictures named SHIPP is basically device-independent, and expressed in three different color spaces. They are 16bit XYZ, 8bit CIELAB and 8bit Calibrated RGB. The last one is based on ITU-R BT.709.

These digital data are now being distributed by the Institute for Image Electronics Engineers of Japan in the form of CD-ROM attached with a technical manual (guide). The manual describes the application format (the contents of TIFF6.0 tag), and statistical data of the individual pictures (such as 3-D information volume, histogram, autocorrelation, etc.) in detail.

The Japanese ISO/TC130 Committee is now proposing SHIPP to the International ISO/TC130 Committee as a new ISO standard.

Appendix 1. sRGB

sRGB defines the monitor viewing conditions as well as the display characteristics of the reference monitor. The reference monitor characteristics are as follows.

1. The color temperature of white point: D65
2. The color coordinates of the primaries:
   - red $x = 0.6400, y = 0.3300$
   - green $x = 0.3000, y = 0.6000$
   - blue $x = 0.1500, y = 0.0600$
3. The matrix converting linear RGB to XYZ tristimulus values

$$A^{-1} = \begin{bmatrix} 0.1424 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0772 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix}$$

4. The decoding equation

$$\text{For } R_{sRGB}', G_{sRGB}', B_{sRGB}' > 0.03928$$
$$R_{sRGB} = [(R_{sRGB}' + 0.055)/1.055]^{2.4}$$
$$G_{sRGB} = [(G_{sRGB}' + 0.055)/1.055]^{2.4}$$
$$B_{sRGB} = [(B_{sRGB}' + 0.055)/1.055]^{2.4}$$

$$\text{For } R_{sRGB}', G_{sRGB}', B_{sRGB}' \leq 0.03928$$
$$R_{sRGB} = R_{sRGB}' / 12.92$$
$$G_{sRGB} = G_{sRGB}' / 12.92$$
$$B_{sRGB} = B_{sRGB}' / 12.92$$

By these definitions, the colors displayed on a reference monitor having the characteristics defined above under the defined viewing conditions are clearly related with the input RGB values.

As SHIPP-Calibrated RGB data are encoded by the opto-electronic transfer characteristics of ITU-R BT.709, the gamma of the displayed image on the sRGB monitor is equal to 1.125[4] relative to the original scene. On the other hand, SHIPP-XYZ data and SHIPP-CIELAB data are associated with the original scene, thus they must be elucidated differently from the colors obtained by displaying SHIPP-Calibrated RGB data on the sRGB reference monitor (i.e., XYZ in sRGB color space).

Appendix 2. Image Quality Evaluation on Print

Preparation of hardcopies for quality evaluation followed the procedure adopted in Kodak Photo CD. Photo CD data are made by encoding the scene data with ITU-R BT.709. To prepare favorable prints from such Photo CD data, a gamma-enhancement is required.

Note 1

An organization jointly managed by the Institute for Image electronics Engineers of Japan, the Japanese Society of Printing Science and Technology, Group B of the Institute of Electronics, Information and Communication Engineers, the Society of Electrophotography of Japan, and the Society of Photographic Science and Technology of Japan.

Note 2

SCID is digital image data standardized, under the support of ISO/TC130/WG2.

References

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