Soft-Copy and Palette-Color Extension for Color Facsimile Standards

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Abstract

In the last several years, tremendous progress has been made toward the development of international standards for Color Facsimile within the International Telecommunication Union—Telecommunication Standard Sector, ITU-T (formerly called the CCITT). The first goal of these efforts is to encode and communicate full-color continuous-tone images using the JPEG image compression standard and the CIELAB color space as the color interchange space. For this goal, ITU-T Recommendation T.42 "Continuous-tone colour representation method for facsimile" and new annexes and revised recommendations for Group 3 and Group 4 facsimiles were developed and approved by ITU-T in 1994. The next goals of these efforts are soft-copy and palletized color image extensions for color facsimile. For soft-copy facsimile, color interchange space and optional color reproduction information are being proposed at ITU-T. For encoding palletized color images and lossless continuous-tone images, the JBIG image compression method is being considered by ITU-T. The recent progress in the above proposals are reported in this paper.

Introduction

In November 1994, after more than four years of standardization work, the continuous-tone color image extensions to Group 3 and Group 4 facsimile were formally approved by the International Telecommunication Union—ITU[1-3]. A new international standard on the specific color space representation for facsimile exchange—ITU-T Recommendation T.42, was also approved[4,6,7].

In the new Color FAX standard, the CIE (1976) L*a*b*—CIELAB color space is standardized as the interchange color space. For encoding of continuous-tone images the JPEG standard[5] was adopted. The JPEG encoding is implemented in a fully compliant manner, encouraging interchange between facsimile and non-facsimile applications. In a Color FAX data stream, the JPEG-encoded image data consist of a series of markers, parameters, and scan data that specify the image coding parameters, image size, bit-resolution, and entropy-encoded block-interleaved data. It was intended that the image data can be passed between Group 3 and Group 4 facsimile services.

The choice of color representation for Color FAX was a subject for intense study and discussion at ITU-T during 1992 and 1993. After an exhaustive study of different color representations, the CIE (1976) L*a*b* space was chosen as a flexible, relatively uniform, and device independent color specification. Since CIELAB is a relative color metric, the choice of illuminant, white point and measurement conditions is necessary to define the representation precisely. The CIE D50 illuminant was chosen in agreement with common practice in the graphic arts industry, along with a perfectly diffuse, 100% reflecting white point. A measurement geometry of 45-0 illuminant to measurement angle is also specified. The choice of gamut range is as follows:

L*=[0,100]
a*=[-85, 85]
b*=[-75, 125]

It was chosen to serve several goals. The default gamut range is sufficiently wide to span existing hard copy output devices. The range is narrow enough to avoid excessive quantization error when the data is represented in eight bits/component. The particular choices of gamut range are believed to represent existing hard copy devices, as well as facilitating effective implementation.

The next goals for the Color Facsimile standardization efforts are soft-copy and palletized color image extensions. In regard to soft-copy, questions relating to color space and gamut range are to be addressed. Which color space is better suited for soft-copy, CIELAB or RGB? Is the CIELAB hard-copy default gamut range also good for soft-copy? For encoding palletized color image and lossless continuous-tone image, will another encoding method, for example, JBIG, be necessary? If so how should its usage be standardized? This paper presents the recent progress in addressing these questions as conducted at the ITU Study Group 8.

Soft-Copy Color Reproduction

During the previous meeting of the ITU-T Study Group 8, considerable progress towards a soft-copy extension to color facsimile was made. The growing popularity of computer-based facsimile transmission and reception makes this a natural and timely addition. The discussion centered around serving this application without compromising interchangeability with hard-copy devices or sacrificing color information accuracy. A detailed contribution from Japan formed the basis for discussion. This contribution[8] detailed the various scenarios under which hard-copy and soft-copy devices might interact, and the implications of color space and gamut range upon those interactions.

The first question to be resolved is choice of interchange space. For hard-copy facsimile, CIELAB was chosen in 1994 as discussed in the introduction above, but CIELAB is not commonly used in personal computers outside of certain professional applications. Most commonly, color data is stored as device-dependent RGB in one of many data formats. Many different RGB primaries, white points and gamma coefficients are used in practice. This would complicate the choice of a single RGB-type space for soft-copy facsimile. In addition, the computational burden of converting between arbitrary RGB spaces is quite similar to the computation required for conversion between CIELAB and RGB.

A larger concern was interworking between hard-copy based stand-alone color facsimile machines and computer-based soft-copy devices. Typically a calling machine does not know *a priori* what type of machine is being called. Requiring a hard-copy based machine to support an additional color space for communication to a computer-based facsimile would complicate implementation considerably. In contrast, computer based applications have relatively flexible resources to handle color space transformations, and these resources are rapidly growing. In light of these discussions, the ITU has elected to retain the use of CIELAB for soft-copy facsimile transmissions, and defer addition of another color space unless and until such use becomes clearly necessary and beneficial.

The second item of discussion is choice of gamut range, the span of color space to be used in encoding color data for soft-copy facsimile application. Currently, the default gamut range is based on hard-copy devices. The range of soft-copy devices is quite different. Measured values taken using D50 and D65 illuminant to calculate CIELAB parameters yielded the following gamut envelope[8]:

$L^*=[0,100]$
$a^*=[-103.5, 98.8]$
$b^*=[-106.8, 96.8]$.

This range is obviously quite different from the hard-copy range listed in the introduction. The ability to reproduce blue is most notably larger for the soft-copy device, with more than 30 E units of additional range in the lower span of b*. Soft-copy devices vary considerably in their ability to reproduce colors at the very edge of the above range.

When the data to be transmitted originates from or is intended to be output to hard-copy, the current default gamut is quite adequate. In the case where the image is synthetic or taken from a soft-copy original, and intended for reproduction on a soft-copy device using the somewhat different gamut available on such a device, the default gamut will not be adequate. For this application the custom gamut option already available within the color fax standard can be used. This option specifies a means to select a gamut which can include the range of colors available on a soft-copy device. In addition, specification of alternate illuminant (and implied white point) is under discussion, and will be enabled. A bit has been reserved for such specification in the DIS/DCS tables.

The specification of a default set of gamut range and white point specifically for soft-copy facsimile is currently under study. Such a gamut range would include the above range. For the time being, use of the custom gamut range option already in the facsimile standards is suggested.

Palette Color and Loss-Less Continuous-Tone Extension

From the beginning of the color facsimile standardization work, JBIG coding scheme was recognized as one of the important coding schemes for color facsimile[9]. The loss-less bit-plane coding scheme such as JBIG is suitable for multi-color images such as bi-color (black and red) image, 1 bit/color component RGB or CMYK image and palletized color image. These images are usually represented by small number of bit-planes, for example less than 8 bits. Conventional bi-level image coding schemes such as MH, MMR support only one bit-plane (i.e. bi-level) image and need some extension to apply to the multi-color images. In addition, they do not obtain high coding efficiency for dithered images. On the other hand, JBIG coding scheme is possible to encode multi-bit-plane images with high coding efficiency using its own specification.

The color facsimile standardization work was divided following two steps in the early stage to progress this work[9];

- First step: JPEG algorithm for continuous-tone image.
- Second step: JBIG for other kind document types, soft copy and progressive build up.

First item of the second step, "JBIG for other kind of document types", corresponds this palette color and loss-less continuous-tone extension. Many proposals and a intense discussions have been made about image representation method, encoding method and mode classification for this extension[10-16]. In this section, the present status of the palette color and loss-less continuous tone extension is reported based on these proposals and discussions in the ITU-T SG8 meetings.

At the beginning of the discussion, only bi-color and 1 bit/color images were considered in the multi-color images. Because, at that time, the discussion concentrated on hard-copy based facsimile. According to the recent progress of computer and communication technologies, computer-based facsimile becomes very popular. Since palette color images are very common in computer systems, we have to consider soft-copy and palette color images in our discussion. We also consider to apply other loss-less coding schemes such as MH and MMR to this extension. Therefore, following items are being considered in the discussion;

- What image types should be supported in the extension?

- Should we add other color space for palette table representation?
- What mode and parameters should be used for JBIG coding method?

Image Types

From above discussion, following kind of images were considered to be supported in this extension:

- bi-color,
- 1 bit/color
- palette color,
- loss-less continuous-tone.

And then, three image types, '1 bit/color' and "loss-less continuous-tone" were selected. As the requirement of bi-color image is slightly different from other images (it may be used simply to distinguish color area from other part,) and even low-cost printers will have 1 bit/color mode, bi-color image mode is not adopted as an independent mode in the mode sequence. One bit/color mode is adopted as a basic color representation method, because it can reproduce full-color images by using dither-like methods, although it may not obtain accurate color reproduction.

Mode Structure

As 1 bit/color image mode is selected as the base mode of the color mode sequence, we can not obtain same mandatory/option relation as in gray-scale and color modes in the JPEG color facsimile. The mode sequence is divided to gray scale and color mode sequences. As the palette color image is represented by small number of colors sampled from the continuous-tone color image gamut, it does not require the same size memory but requires the same reproduction accuracy as that of continuous-tone color mode. Therefore, both modes are treated as one coding mode.

According to these discussions and consideration about bits precision, following mode sequences are being proposed:

(a) Color mode sequence

1) 1 bit/color comp. (RGB and CMY(K) 1 bit/comp. image)
2) 8 bits precision palette and continuous-tone less than equal 12 bits entries 8 bits precision palette
less than equal 8 bits continuous-tone
3) 12 bits precession palette and continuous-tone less than equal 16 bits entries 8 or 12 bits precision palette less than equal 12 bits continuous-tone.

(Each of the above modes shall support all prior modes as numbered.)

(b) Gray scale mode sequence

1) 8 bits continuous-tone
2) 12 bits continuous-tone
3) 16 bits continuous-tone

(Each of the above modes shall support all prior modes as numbered.)

Color Space for Palette Color

Since palette color mode is mainly used in the soft-copy application, we considered to introduce RGB color space at first. But finally, we agreed to use CIELAB color space defined in Rec. T.42 in present state. Because, other color space is not introduced in the soft copy extension as discussed in the soft-copy color representation section, and we can interchange palette color image data easily and accurately, so long as we use a device independent interchange color space such as CIELAB for representing the color palette table in the communication.

JBIG Coding Mode and Parameters

Since there are many options to use the JBIG coding scheme for this extension, following modes and parameters are being proposed:

- Single progression sequential mode
- Stripe and plane interleaves are supported
- Stripe interleave (128 line/stripe) is mandatory
- APPI marker that was introduced in JPEG color facsimile is used for specifying parameters that includes palette table.

Conclusion

The recent progress concern about soft-copy and palletized color image extensions in ITU-T SG 8 was reported. These discussion's results will be summarized and submitted to the next ITU-T SG8 meeting as draft new recommendations; Rec. T.42 extension, T. Palette-colour and other related revised recommendations for Group 3 and 4 color facsimile.

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