An International Standard for Color Facsimile

Andrew H. Mutz and Daniel T. Lee
Hewlett-Packard Laboratories, Palo Alto, California

Abstract

The new standard for color FAX has been approved in the past year. Several aspects of this standard are discussed with attention to implications on flexibility, device independence, and color accuracy. The baseline standard for facsimile provides the means to transmit 24-bits/pixel color data in the CIE L*a*b* color space. The base resolution for this hard copy based system is 200 dpi. The data is coded using JPEG, and the lossy DCT-based mode is used. The degree of lossiness is not mandated by the standard, but chosen by the transmitter. The DCT coefficients are entropy coded using Huffman coding. Further details of the basic mode and options currently in the color fax standard are presented. Possible extensions of the standard to soft copy image transmission, alternate illuminants, lossless coding, and multicolor document coding are discussed.

Introduction

The transmission of images over wire was first accomplished in the 19th century, with the first commercial use introduced in 1865. Transmission of color images using analog signals over wire was reported by Bell Laboratories in 1925[1]. Though niche markets such as newspaper companies have used telecommunications of images since the 1940's, facsimile standards for color (analog or digital) have been absent until recently.

The standardization of image formats and transmission means for telefacsimile is handled through the International Telecommunications Union-Telecommunications Sector, or ITU-T (formerly the CCITT). This body consists of representatives from member countries and delegates from companies, agencies and countries. Telecommunications standards developed within the ITU are approved by member countries and published by the ITU for implementation worldwide. The facsimile communications standards are among the most successful and widely used of these standards. The Group 3 facsimile standard, a digital protocol designed to operate over analog data channels, was formally approved in 1981. It is the most widely used of the two standards in which color facsimile has been approved. It is used throughout the world over general switched telephone networks. The Group 4 standard, designed to operate over digital channels, is implemented in a more limited set of regions. Recent extensions of the Group 3 standard also allow the use of this protocol over digital channels.

A Group 3 facsimile transmission is organized into multiple 'phases', including call establishment, negotiation and training, message transmission, post-message communication, and call release[2]. During phase B, the capabilities of the receiving machine are transmitted to the sending machine, and the sending machine selects a subset of these capabilities. This subset is communicated to the receiving machine. This negotiation process enables communication between fax machines of different capability, since each machine must implement at least the most basic capabilities. For example, the sending machine may have color capability while the receiving machine can only receive monochrome images. In this case, transmission of a document in black and white will occur. The Group 4 standard is structured quite differently, but functions in an analogous manner.

The first serious proposals for adding a color extension to facsimile were presented to the ITU (formerly CCITT) in 1990[3]. A proposal by NTT of Japan to add color image transmission to Group 4 facsimile was made. In this proposal, color documents were subdivided into full color, multicolor, bi-color, and mixed documents. The coding of full color documents was to be addressed first, using the JPEG (Joint Photographic Experts Group) coding standard[4] under development since 1986, and approved by the ISO in 1992. The coding of multi-color and bi-color documents was to be addressed next using the JBIG (Joint Bilevel Image Experts Group) coding scheme[5], approved by the ISO in 1993. During the November 1993 ITU meeting, the decision was made to progress Group 3 and Group 4 color fax standards simultaneously.

The first part of this work has now been completed, and the facsimile standard for transmission of continuous-tone color and gray-scale documents was approved at the June 1994 ITU meeting in Geneva. This standard now awaits only formal approval before publication in March 1995.

Color Representation

The choice of color representation was the result of a cooperative effort between delegates within the ITU, and was the subject of intense study and discussion during 1992 and 1993. The Japanese delegation in particular performed an exhaustive study of different color representations. The result of this work was in agreement with published work in the United States[6]. CIE (1976) L*a*b* space (CIELAB) 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. These measurement conditions are defined as an ISO standard for graphic arts measurement[7]. The digital representation of the image data was next determined. 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 conversions from real values in CIELAB to the eight-bit integer representations are performed as show:

$$L = (L^*) * (255/100)$$
$$a = (a^*) * (255/170) + 128$$
$$b = (b^*) * (255/200) + 96,$$

where L, a, and b represent eight bit integers, and L^*, a^*, and b^* represent real numbers.

Following successful negotiation, any alternative gamut range may be specified by the transmitter. This is intended to allow for soft-copy device gamuts or for more accurate specification of colors within a narrower gamut range. In addition, 12 bits/channel of data may be transmitted as an option.

Spatial Representation

The spatial resolution chosen as basic for color facsimile is 200×200 pels/25.4mm. This spatial resolution is familiar in most fax machines as the "fine mode." The chrominance channels a^* and b^* are subsampled to 100×100 pels/25.4mm using a symmetric 4-tap filter. This reduces the number of DCT calculations needed for image coding, and takes advantage of the lower visual sensitivity to chroma modulation. The locations of the pixels may be represented as shown:

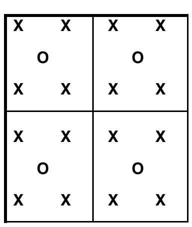

Figure 1. Positions of pels centers following chroma sub-sampling. **X** *represents lightness pel centers, and* **O** *represents chroma pel centers*

In addition, optional spatial resolutions of 300×300 and 400×400 pels/25.4 mm are available upon successful negotiation, as is a non-subsampled chroma mode.

Image Coding

Image data is encoded using the baseline mode of the "JPEG" standard. This Discrete Cosine Transform (DCT) based lossy compression scheme is widely used for image compression, and is robust over a wide range of selected "lossiness." It is computationally intense re-lative to the modified Huffman and modified Read coding methods currently most common in Group 3 facsimile.

The image is first divided into many square blocks of pixels, and each block is DCT-transformed. The DCT is a block transform which is, by itself, lossless. In the JPEG standard, an 8×8 pel transform is used. The 64 components produced by the transform are quantized by multiplication with a "Quantization Table" of 64 elements. The higher frequency components are assigned smaller multipliers, and in a typical image many of these elements will be represented as zero following this step. The resulting coefficients are then entropy encoded using Huffman coding. This is repeated for all the blocks in the image.

Image Data Structure

The JPEG standard specifies a method for image compression and a syntax for the representation of the compressed image. This syntax, while providing for multiple image planes, does not have a specified color coordinate system. The CIELAB color space is used for this application of the coding standard. The color fax standard implements JPEG in a fully compliant manner, encouraging interchange between facsimile and non-facsimile applications. For example, although a "preferred", or predefined set of Huffman tables has been specified for color fax, the data stream for each color fax page includes the Huffman tables used.

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. The data stream is encoded for facsimile transfer using the error correction mode (ECM) specified in the Group 3 protocol, the ITU-T Rec. T.30 Annex A. The JPEG data structure for this application has the following elements, as specified by JPEG ITU-T Rec. T.81 Annex B: Parameters, markers, and entropy-encoded data segments.

Optional Features

The basic values of the color fax standard are designed to allow the efficient transmission of hard-copy continuous-tone image data. The optional features included in the color fax standard are chosen to provide additional flexibility for applications. These features include higher spatial resolution, no spatial sub-sampling, 12 bits/plane bit precision, and custom gamut range. These options are only available following successful negotiation between terminals. In addition, the JPEG restart marker is supported. This marker permits re-synchronization of the entropy encoded data in the event of data loss. This option may be used without prior negotiation. The optional use of a custom illuminant is under study.

Planned Extensions

The ITU Study Group 8 committee intends to continue the development of the color fax standard. These extensions include soft-copy gamut definition, a recommendation for hard-copy–soft-copy interchange, the encoding of multi-color image data using other coding methods such as JBIG, and further study of the need for optional illuminants.

References

1. H. E. Ives, J. W. Horton, R. D. Parker and A. B. Clark, The Transmission of Pictures over Telephone Lines, *The Bell System Tech. Jour.*, April, 1925, pp. 187-215.
2. ITU-T Rec. T. 30, Procedures for Document Facsimile Transmission in the General Switched Telephone Network, *ITU*, 1994.
3. M. Matsuki and D. T. Lee, Development of Color Facsimile Standards: An Overview, *SID Digest of Tech. Papers,* Vol. **25**, 1994, pp. 883-886.
4. ITU-T Rec. T.81, ISO/IEC 10918-1, Information Technology – Digital compression and coding of continuous-tone still images, Part 1: Requirements and guidelines, *ITU*, 1993.
5. ITU-T Rec. T.82, ISO/IEC 11544, Information Technology – Coded Representation of Pictures and Audio Information - Progressive Bi-level Image Compression, *ITU*, 1993.
6. J. M. Kasson and W. Plouffe, Subsampled Device-Independent Interchange Color Spaces, *Image Handling and Reproduction Systems Integration*, *Proc. SPIE* **1460**, 1991, pp. 11-19.
7. ISO/TC 130 DIS 13655, Graphic Arts Technology-Spectral Measurement and Colorimetric Computation for Graphic Arts Images, *ISO*, in preparation.