New Developments in Color Facsimile and Internet Fax

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Abstract

This paper describes the recent developments in the ITU and IETF toward a mixed raster content mode for color facsimile and a TIFF-based file format for facsimile data. The Mixed Raster Content (MRC) mode, scheduled for approval by the ITU in October 1997, enables the efficient processing, interchange and archiving of pages containing a mixture of color and black-and-white images. MRC uses a 3-layer model to segment an image into layers, which are coded using existing black-and-white and color facsimile methods that are matched to the content of the layer. The MRC model allows the differing requirements of text, line art and pictures to be simultaneously met within a single fax data stream. The MRC model has also been proposed as an architectural framework for JPEG 2000. Internet fax is progressing within the ITU and IETF. Recent attention has been focused on TIFF as a file format for facsimile data, and this paper will describe the status of ongoing work on file format proposals.*

Introduction

The facsimile systems that most people are familiar with today are black-and-white, conforming to standards set by the ITU-T (Telecommunication Standardization sector of the International Telecommunication Union, formerly known as the CCITT). These standards specify the protocols[1] and bi-level coding procedures[2-5] that sending and receiving stations use to 1) establish and manage a real-time connection, 2) agree on a data representation and transmission parameters, and 3) transmit and receive image data. These standards provide three things: acceptable levels of performance and quality, a common reference point for equipment manufacturers and implementors and interoperability among users. Together with the ubiquity of the public switched telephone network (PSTN), these standards have led to the explosive growth in Group 3 black-and-white facsimile that has occurred since 1980.

The same convenience and ease of use for color facsimile requires wider use of color scanners, displays and printers; faster modems and communication channels to handle the increased data volume; and equivalent standards for color facsimile. These enablers are already being put in place. For example, the ITU-T last year approved V.34 for facsimile, which supports data rates up to 33.6 Kbps, and it is now available commercially in fax machines. This paper will focus on new standards being developed to provide enhanced color facsimile services over both the PSTN and the Internet.

Color Facsimile Standards

The ITU-T has already approved two Recommendations or standards for color facsimile: T.42 in 1994 and T.43 in 1997. ITU-T Rec. T.42[6,7] is the base mode for color and grayscale facsimile, which all ITU-conforming fax applications must support if they implement color. This mode is intended for pictures and uses JPEG for the lossy compression[8] of L*a*b* color data or L* grayscale data. Standard resolution is 200 pixels per inch (ppi) in both x and y directions. In October 1997, the ITU-T is scheduled to approve 100 ppi as an optional resolution, as well as making 300 ppi and 400 ppi separate options for color, independent of their use in black-and-white facsimile.

ITU-T Rec. T.43[9,10] is an optional mode for color facsimile, which uses JBIG[5,6] to losslessly compress one bit per color CMY, CMYK or RGB images or palettized (i.e. mapped) and continuous tone L*a*b* images. To code multi-level images using JBIG, which is a bi-level compression method, an image is resolved into a set of bit-planes using Gray code conversion, and each bit plane is then JBIG compressed. This mode is intended for color graphics and text, and can be used for halftoned color separations.

The existing black-and-white and color facsimile standards each define a single coding method for use within a facsimile session. Each method was designed for a different kind of content or performance level: T.4 MH (Modified Huffman) and MR (Modified Read), T.6 (MMR Modified MR) and T.82 (JBIG) are fine for black-and-white text; JBIG is preferred when there are black-and-white halftones, T.81 (JPEG) is best for pictures or photographs, and multi-plane JBIG is intended for colored charts, text, graphs and the like.

This raises the question of what coding method to use for a page containing a mixture of black-and-white text, color pictures and color graphics. No single coding method, comprising compression algorithm, spatial resolution and color representation, is optimum for all kinds of content. This pointed to the need for a single standard with acceptable performance on pages containing black-and-white *and* color content.

* In October 1997, the ITU formally approved Mixed Raster Content (MRC) mode as ITU-T Recommendation T.44. In February 1998, the IESG (Internet Engineering Steering Group) approved the TIFF-FX Internet Draft as a Proposed Standard and published it as RFC 2301.

Mixed Raster Content (MRC) Fax

Development

To address this need, ITU-T Study Group 8 formed an ad-hoc group on Mixed Mode in February 1996. The goal of this group was "a framework for mixed mode for bi-level and multi-level image data for facsimile."

From the start, the ad hoc group focused on multi-layer models, where the black-and-white content would be in one layer and the color in another. This approach would enable existing ITU-T coding methods to be applied on a layer-by-layer basis, ensuring compatibility with existing standards and avoiding the time-consuming development of a new compression standard.

In the end, the group settled on a 3-layer model, proposed in a joint HP/Xerox contribution made in June 1996. Progress was relatively rapid. The technical details were completed in February, 1997 and ITU-T Draft Recommendation T.44, Mixed Raster Content (MRC)[11] was circulated for country balloting. The Recommendation is scheduled for final approval in October 1997. When approved, the T.44 standard will be another optional mode for color facsimile.

Model

The 3-layer MRC model represents a color raster image as two multi-level or color layers (Foreground and Background) and a bi-level layer (Mask) that describes how to combine them to reconstruct the color raster image (Figure 1). When the Mask layer pixel value is 1, the corresponding pixel from the Foreground layer is selected; when it is 0, the corresponding pixel from the Background layer is selected.

The bi-level Mask image can contain text characters, line art, filled shapes or filled regions. The Background layer typically contains continuous tone images, while the Foreground layer typically contains the colors of the text, line art and other shapes or regions on the page.

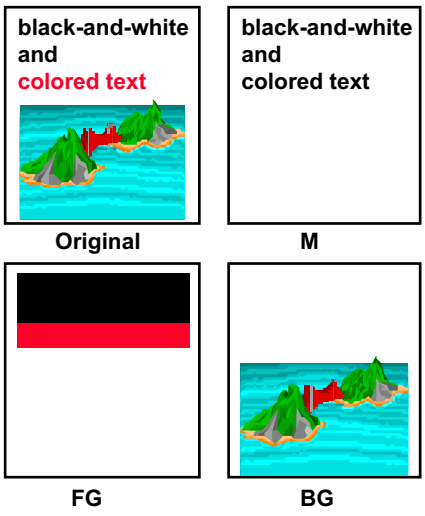

Figure 1. The MRC model represents an original as a bi-level Mask (M) layer and color Foreground (FG) and Background (BG) layers.

Figure 1 shows a page with colored text and a colored image. It illustrates the use of all three layers in the MRC model. Wherever the Mask layer is black, corresponding to the text characters, the image uses the color from the Foreground layer, which contains rectangles filled with the text colors. Otherwise, the image uses the color from the Background layer, which either contains the colored image or is blank.

Other pages may use one or two layers or use the layers differently,[11] depending on the segmentation that converts a raster image into layers. For example, a page containing a picture would use only the Background layer. A page of black-and-white text would use only the Mask layer, with the Foreground layer defaulted to black and the Background, to white. A page with black text and a picture would use the Mask and Background layers, with the Foreground defaulted to black. A page with text and a color bar chart would be represented by a combination of the Mask and Foreground layers, or by the Foreground layer alone. When two layers are used, the Mask layer must be one of them. In other words,. the only combination of layers not permitted is Foreground and Background together, without a Mask layer. While the decomposition of an image into the layers depends on the segmentation and is not unique, the reconstruction of an image from layers is uniquely specified by the MRC model.

Coding

The benefits of the MRC model are obtained by segmentation of the image content into multiple layers, each of which can then be coded using a compression scheme, spatial resolution and color representation matched to its content. Text, line art and color images have differing requirements for encoding. Text or line art requires relatively high spatial resolution for legibility, while a picture usually needs higher color depth but can tolerate a lower spatial resolution. By partitioning an image into layers, the MRC model makes it possible to meet these differing requirements layer by layer within a single fax data stream.

Each layer of the MRC model uses a single ITU-T coding method. In this way, the MRC fax mode will allow multiple compression types, color spaces and spatial resolutions to coexist within a single page. For example, the Mask layer can have a spatial resolution of 100, 200, 300 or 400 pixels per inch and use any of the existing methods for black-and-white facsimile coding (MH, MR, MMR or JBIG). The Background and Foreground layers would use Rec. T.42 or Rec. T.43. These layers have spatial resolutions that both conform to ITU-T recommended values and are integer factors of the Mask layer resolution. For example, if the Mask layer resolution is 400 ppi, then the Foreground and Background resolutions could be 400, 200 or 100 ppi; if the Mask resolution is 300, then allowed resolutions are 300 and 100. The MRC mode requires that the spatial resolution be the same in both directions.

Image Structure and Strips

Because facsimile equipment can have limited memory, the MRC fax mode also allows for a page to be divided into page-width horizontal strips. A strip can have one, two or three layers, depending on its content. The MRC fax mode requires that conforming implementations support a strip size of at least 256 lines. Strips can be narrower, based on page content, and implementations may optionally sup-

port page-sized strips. Maximum strip length does not apply to single layer strips, which are equivalent to using one of the existing facsimile standards and like them are limited only by page length.

Classifying a strip according to the number of layers it contains allows further efficiency in representation by eliminating the need to compress superfluous layers. For example, the page in Figure 1 has text at the top and a picture at the bottom. Instead of representing this page as a single strip with 3 layers, each with large portions that are blank, this page can be represented by two strips. The first strip at the top of the page has only Mask and Foreground layers for the text, and is followed by a strip with only a Background layer for the picture.

When present, the Mask layer is required to provide data for the entire strip. However, the color data in the Foreground and Background layers may cover only a portion of a strip. Only the area covered need be encoded. This is accomplished by giving the horizontal and vertical offset to the upper left corner of the area. The multi-level coding methods used for these layers then give the width and length of the area. Outside this area, the MRC data stream specifies default colors for the Background and Foreground layers.

The MRC fax mode requires that the Mask resolution be the same for all strips on a page. It also requires that the Background and Foreground layers resolutions be integer factors of the Mask layer resolution. However, there is no requirement that it be the same integer factor for all strips. For example, if the Mask resolution is 400 ppi, the Background layer resolution can be 200 ppi in one strip but 100 ppi in another.

Data Stream Structure

Each page in an MRC fax data stream consists of four parts: a Start-of-Page (SOP) Marker Segment, an optional additional parameters segment, page data, and an End-Of-Page (EOP) Marker. The SOP marker segment can be further subdivided into an SOP marker and page-level parameters. These parameters include the segment length, identification of the coders used for the Mask, Background and Foreground layers, the Mask resolution and the page width.

The optional additional parameter segment consist of entries that provide image reproduction information. The only two entries so far defined specify the gamut range and illuminant for interpreting the L*a*b* color data. Other entries are for further study.

The page data consists of one or more strips, in sequence from the top of the page to the bottom. Each strip consists of a Start-Of-Strip (SOSt) Marker Segment and strip data. The SOSt Marker Segment comprises an SOSt Marker and strip-level parameters. These parameters identify whether the strip has 1, 2 or 3 layers, give the strip length and specify the default colors and the horizontal and vertical offsets of the Background and Foreground layers within the strip. The strip data has Mask layer data first, followed by the Background and then Foreground layer data.

In the MRC fax mode, the layers use the ITU-T coding methods indicated by the Mask-Coder and Background-and-Foreground-Coders parameters in the SOP Marker Segment. These methods are specified in existing black-and-white and color facsimile standards. In Group 3 applications, the coding mode and resolution of the Background and Foreground layers are defined in the layer data. (Resolutions that conform to the MRC fax mode are integer factors of the Mask resolution.) No additional markers are added to the layer data.

Future Extensions

Several extensions to the MRC base mode have been identified for further study. They include: using more than 3 layers, allowing multiple elements in a layer, adding rendering information to the additional parameters segment, and allowing other compression schemes as they become ITU-T standards.

Results

The MRC approach was applied to encoding the ITU-T 4-Color Printing Facsimile TestChart 4CP01. The chart was scanned on a UMax PowerLook scanner at 300 ppi and written out as a 25.8 MB TIFF file. This image was then split into a black-and-white layer and multiple color layers. It should be noted that YCrCb color space was used instead of L*a*b*. Since both are non-linear luma-chroma color spaces, using one instead of the other was not expected to significantly affect the results reported here.

The Mask layer was compressed at 300 ppi using MMR. The color layers were scaled to 100 ppi and compressed with JPEG using the default Q tables and a Q factor of 75. The results were written out in the form of a TIFF file, which had a size of 28 1 KB. Compared to the original, this corresponds to 0.26 bits per pixel or a compression ratio of about 92:1. The results demonstrated fax quality text and color images. At this compression ratio, it would take a little over a minute to transmit this page using a 33.6 Kbps modem. Transmission time and image quality depend of course on page content, segmentation, and JPEG parameters.

JPEG 2000

The 3-layer MRC model defines a general approach to using and managing multiple compression schemes. The MRC fax mode defined in ITU-T Draft Rec. T.44 is the result of using this model with compression schemes that conform to existing ITU-T Recommendations. The MRC model itself is compression-algorithm neutral.

Currently underway within the ISO is the JPEG 2000 activity calling for the development of a new standard for the compression of still imagery. This activity is inviting contributions on compression architectural frameworks and on compression algorithms. In particular, the architectural framework contributions would include "concepts that do not necessarily specify a particular algorithm, but instead specify an implementation, format, or methodology which may contain multiple algorithms and/or definitions and management functions."[12]

Because of the similarity between the goals of the JPEG 2000 architectural framework and the MRC model, Xerox submitted an MRC-based contribution to ISO in July 1997. This contribution proposed the ITU-T Mixed Raster Content model as the JPEG 2000 architectural frame-work.[13] ISO is accepting contributions until November 1997 and work on converging the different contributions will begin in 1998.

Internet Fax

Within the last year, Internet fax has attracted standards activities, both within the ITU-T and the IETF (Internet Engineering Task Force). Late in 1996, the IETF formed an Internet Fax Working Group. Its charter includes enabling standardized messaging-based fax over the Internet and eventually devising standards for session-based fax over the Internet.

Within these forums, discussions are ongoing as to the relationship between Internet and conventional fax services. The latter offers a real-time connection with immediate confirmation of receipt. By comparison, Internet fax is being discussed in terms of e-mail messaging, store-and-forward services and a reasonable emulation of conventional fax services.

One point around which a consensus has been emerging is the use of TIFF as a file format for Internet fax. The compressed page data from a multi-page fax session would be stored in a multi-page TIFF file, with one IFD (Image File Descriptor) per page. The tagged fields that TIFF requires to describe the image data would have values conforming to the ITU-T standards that correspond to the compressed data.

As of September 1997, three TIFF-based file format proposals have been submitted as Internet Drafts to the Internet Fax Working Group. (Internet Drafts are temporary document that expire six months after they are posted; the current Drafts are available though the Working Group's home page at http://www.ietf.org/html.charters/fax-charter.html.) One is based on TIFF Class F, which was originally developed in 1989 for black-and-white fax as it was then practiced. Supported by the EMA Voice Profile for Internet Mail (VPIM) Work Group, the TIFF-F proposal aims to update TIFFClass F to bring it in line with current black-and-white fax practice. It is intended to provide a stable reference for implementors who currently use TIFF in black-and-white fax applications.

The second, sponsored by the Japanese WIDE (Widely Integrated Distribute Environment) project, specifies a minimum set of coding parameters. This set corresponds to the mandatory black-and-white capabilities defined by the ITU: MH compression, 204 ppi x-resolution, 98 or 196 ppi y-resolution, and an image width of 1728 pixels. All implementations would support this set and could use it without negotiation. There has been general agreement that Internet Fax requires the definition of a minimum set of capabilities, just as ITU-T fax does.

The third is a joint Adobe/Xerox proposal, formally called TIFFPlus but known informally as TIFF-FX (FX stands for Fax eXtended). This proposal was intended to be a single reference for a TIFF-based Internet fax file format. It defines a minimum set of file format capabilities (like the second proposal), captures existing black-and-white practice (like the first proposal), and adds JBIG capability. Unlike the other proposals, it also supports the ITU-T Recommendations T.42, T.43 and T.44 for color facsimile. The extension to color is significant as other Internet image formats, such as JFIF and PNG, are color-capable. The Adobe/Xerox proposal also describes an optional IFD for storing session-related information.

Also being proposed is an updated definition of the MIME image/tiff content type that would align it with the current TIFF specification.[14] The definition of this content type includes an optional parameter *application*. The *application* parameter corresponds roughly to ITU-T fax mode and identifies the ITU-T Recommendation to which the file's image content conforms. For example, application would be B for the minimal set,C for the T.42 base color mode, M for the T.44 MRC mode, and so on. The *application* parameter would also define conformance levels that are consistent with ITU-T implementations.

At the time this was written, work on progressing and merging these proposals is ongoing. According to the draft minutes of the August 1997 meeting of the Internet Fax Working Group, the authors have been "directed to complete the integration between [the] TIFF-F and TIFF-FX [proposals] in the TIFFPlus document." If and when this integration is complete, then TIFFPlus would become the single document agreed upon by all interested parties. It could then become a proposed standard, the first step enroute to becoming an Internet standard.

At its August 1997 meeting, the TIA TR 29 Committee proposed supporting "a primitive mode of e-mail facsimile and the use of TIFF as a facsimile image file format." This committee recommends the official US position on ITU-T facsimile standards activities. TR 29 is proposing two levels of e-mail-based facsimile: primitive (or simple) and normal. The simple mode, similar to the WIDE proposal, would define a minimum set of common capabilities. For the normal mode, TR 29 proposes that TIFF-FX should be used, which is compatible with the direction expressed at the August meeting of the Internet Fax Working Group.

This account of Internet fax is a snapshot of a changing area in which positions are being refined and agreements still being developed.

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