Color and Image Management for Telecommunication Applications

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Abstract

The exchange of still color images of all quality levels between homes and businesses over the information superhighway promises to bring an exciting new array of services and functions to consumers that will spawn entirely new businesses. The success of these new businesses will depend on the communication and delivery of a value proposition to the customer that is both timely and desired. This will in turn depend on the establishment of standards, protocols, and architectures that produce both economies of scale and the flexibility to serve the widest markets. This article discusses some of the color and image aspects of those standards and architectures, with specific reference to the pixel and image processing functionalities required to manage the BCD's or bits, colors, and dots of such systems.

Introduction

The evolving infrastructure of the information superhighway will be able to support a wide range of imaging applications from low resolution entertainment such as video-on-demand to the high resolution image exchange of the medical and graphics arts industries. This wide range of applications and businesses will put pressure on the flexibility of the storage, processing, manipulation, and delivery of image data throughout the telecommunication network.

Some applications will be best served by centralized functionality that simplifies transmitters and receivers. An example, is a cable home shopping service where a customer can browse through a catalogue of color images and information using his TV remote, get high quality color prints, and make purchases. The service can know or initiate a query about the characteristics of the output equipment in each home and pre-process the image data to match the quality of that equipment prior to transmission. The catalogue data can be stored at various resolutions in a well defined color space with a large color gamut to service the range of output qualities. This centralized functionality allows for an economy of scale and low cost devices in homes with the disadvantage that the central facility has to manage the BCD's or bits, colors, and dots across many output devices, e.g., TV's, CRT's, and digital printers using inkjet, dye sublimation, electrophotography, and thermal wax. For N out-

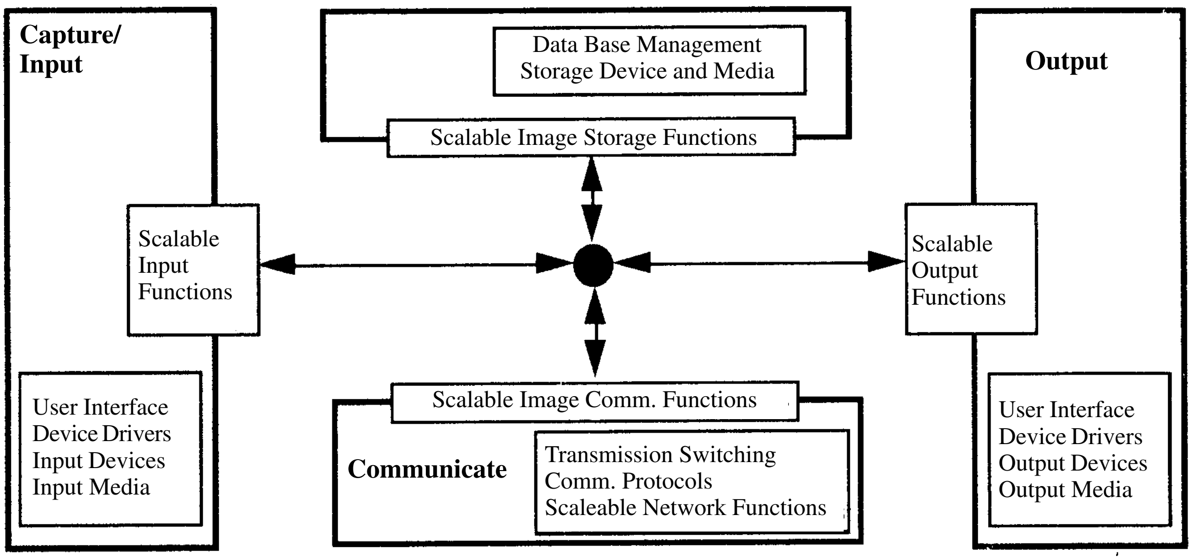

Figure 1. Reference architecture for general image telecommunication

put modalities the complexity is O(N). For point-to-point applications like image sharing between homes or offices, the complexity significantly increases to O(NM) with M being the number of unique input modalities. Since images can come from many sources including video cameras, digital scanners, digital cameras, medical and scientific imagers, computer applications, Kodak's PhotoCD, and many mediums, e.g., slides, prints, negatives, textiles, paints, phosphors, and art, it is easy to see that M can be much larger than N. To serve all these markets, telecommunication architectures need to be flexible, scaleable, and robust with movable and sharable functionality, and they need to support and execute most of the necessary functionality without user interaction. Such a reference architecture is illustrated in Figure 1 where the operating system at the system interconnect provides for distributed functionality including image processing, image manipulation and editing, image data management and format conversion, image security, and applications and authoring tools to support the various services and markets.

The next section will present some of the color and image specifics of the BCD 'impedance matching'. Section three will go into more detail about architectural tradeoffs, and the last section will present the conclusions.

Color and Image Management

Color management at the operating system level is just now arriving on the desktop.[1] Numerous applications in science and medicine as well as shopping, advertising, travel, and graphics make it important to extend these solutions to image telecommunication. Fortunately the architecture of the evolving desktop solution is extremely well suited to telecommunication. On the desktop, each input and output color space is separately defined in terms of one of three profile connection spaces (PCS), either 8 or 16 bit CIELab, or 16 bit XYZ. Color profiles can be attached to the image data or referenced from data bases. In general, input image data is not converted into one of the PCS's because any discrete conversion is lossy. Rather, the image data is stored as it is inputted and when it is displayed or printed it is converted to the output color space through a new color profile derived by linking the input color profile to the output color profile at equivalent PCS colors. Profiles can be multi-dimensional look-up-tables, matrices, one-dimensional look-up-tables, or combinations. For telecommunication applications where storage and bandwidth are at a premium it is unlikely that attaching color profiles to images is the preferred solution, and storing images in input and output device dependent color spaces would be quite awkward to manage and suboptimal for compression. A better solution is one that actually converts the input image data into an interchange color space for storage and transmission where the interchange space could be one of the PCS spaces. There are a variety of factors that must be considered in choosing an interchange color space including familiarity, compression performance, conversion complexity, color gamut, and susceptibility to errors. Recent studies[2] in support of the color facsimile standard have shown that CIELab is slightly preferred overall with other non-linear luminance/chrominance color spaces exhibiting similar performance and linear color spaces, e.g., XYZ, being significantly worse. For this reason, CIELab has been chosen as the color facsimile standard[3].

In the most general application telecommunication systems will have to managed the bits and dots as well as color. All input technologies are contone meaning that they have 8 or more bits/color. Computer displays, digital games, and digital TV's are also quickly moving toward 8 and more bits/color. The exception is the installed base of digital color printers which are primarily binary with only 2 levels/color. Color inkjet, laser, thermal wax, and high-end image setters in graphic arts fall in this category. Input and output devices also cover a wide range of DPI or dots per inch. Computer monitors are typically 75 DPI. Inkjet printers are 300-600 DPI, and mid-range to high-end image setters are 1000-3600 DPI. Filtering and downsampling, interpolation, and single and multi-bit halftoning will be required to map across these technologies. On the desktop, these functions are provide by operating systems, applications, and device drivers with a growing use of page description languages such as Postscript. In image telecommunications, where raster data is prevalent and multi-user performance is critical, they will most likely be implemented by the network or service provider, or they will be integrated into custom electronics in end user terminals, i.e., settop boxes or modems. Regardless of the implementation, however, there are a number of key issues such as functional ordering and scalability that can significantly effect the architecture. These will be discussed in the next section.

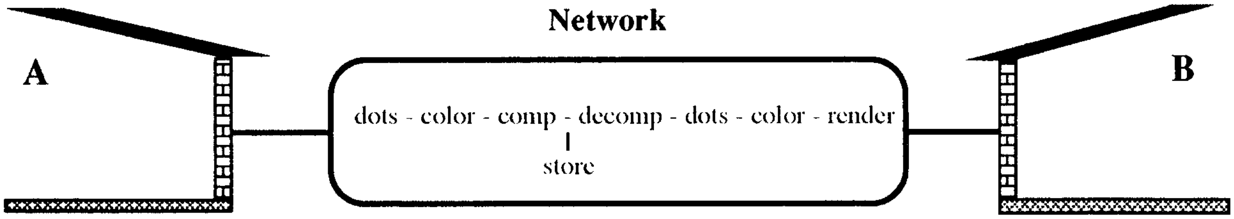

Figure 2. Color and image management for all network solution

Architectures for Image Telecommunication

As mentioned above, the key characteristics of images, devices, and media to consider in choosing an architecture for image telecommunication are the bits, colors, and dots. Each input and output device can have a different number of bits and dots, and a color space that depends on the device. Mapping among device/media combinations can require processing in each of these characteristics. In addition, to optimize the use of storage or transmission bandwidth it is important to incorporate image compression into the imaging chain. The order of this processing in an image telecommunication system is a key element its architecture. Defining render as the bit mapping and dots as the dot mapping, Figure 2 shows the preferred order of these operators for converting from an input device at A to an output device at B where all processing occurs in the network and uncompressed data is transmitted. This solution produces the lowest cost end devices at A and B.

Other orderings are possible but they are generally less desirable. To examine this further, it is instructive to analyze the number of bits and dots required for high quality output as a function of image type. This is shown in Figure 3 based on unpublished visual studies at Kodak, where the curve marked Info refers to equal information points. Since the Text curve is parallel to the Info curve and the Photo curve has a lower slope, the figure indicates that bits and dots are equivalent sources of information for text but that bits are better than dots for photos and compound documents. To minimize the storage requirements in the network, this leads to the conclusions in Table I. These conclusions also apply to the distributed architecture where the role of the network is simply to store and transmit the image data with dots - color - comp at the transmit site A and decomp - dots - color - render at the receiver site B.

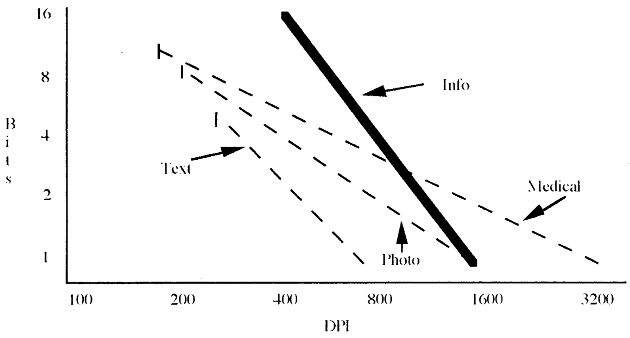

Figure 3. Bits/Dots Requirements for High Quality Images

Depending on the compression algorithm and the amount of color, photo, graphics, and text data in the image, it is possible that the minimum storage for the last case in the table could arise from placing the rendering prior to compression as in today's facsimile giving the order color - render - comp - decomp. In this case, the color transformation would be into the device-dependent color space of the output and the compression algorithm would have to be lossless. In addition, since 300/8 is higher quality than 300/1, the comparison needs to be made with a lossy compression that only preserves the quality of the 300/1 output. Example results are shown in Figure 4 for Jpeg and Group III compression, illustrating the fact that, in terms of compression performance, rendering prior to lossless compression is preferred only for pure text.

The architecture in Figure 2 also allows for broadcasts to multiple B sites from a single A transmission, assuming that dots is either the identity operator that preserves the input quality or that multiple resolutions are generated for each output as in the Kodak PhotoCD system eliminating the need for dot or resolution processing on output. The PhotoCD color space, PhotoYCC, also includes the input color conversion and it can be used as an alternative to CIELab for interchange.

Table 1. Preferred Orderings for Image Functionality

Input (DPI/Bit)	Output (DPI/Bit)	Preferred order to minimize network storage
300/8	300/8	color-comp-decomp-color (dots=render=I)
300/8	150/8	dots-color-comp-decomp-color (render=I)
300/8	1600/1	color-comp-decomp-dots-color-render
300/8	1600/8	color-comp-decomp-dots-color (render=I)
300/8	300/1	color-comp-decomp-color-render (dots=I)

Extensions from its current 8 bits/color to 10 or 12 bits/color can also provide for larger dynamic ranges and smaller quantization errors. Studies at Kodak have shown that the 8, 10, 12 bit CIELab rms errors for all hardcopy colors are 1.5, 0.4, and 0.1 respectively, with 1 count density values of 2.91, 3.29, and 4.08. The 8 bit results are sufficient for all desktop and mid-range applications, and the 10 and 12 bit results are excellent for high end graphics and medical systems.

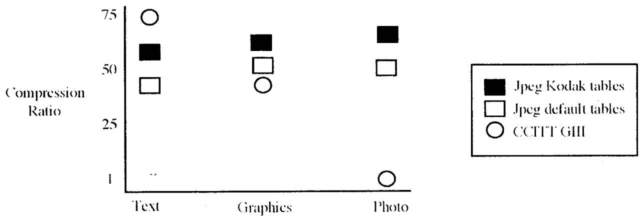

Figure 4. Comparison of 8 bit unrendered Jpeg and 1 bit rendered CCITT GIII

Conclusions

The optimal method for managing image bits, colors, and dots in telecommunication systems is dependent on the application. To support all applications from low-end to high-end with various image sizes, input and output color spaces, transmission speeds, and device costs, the architecture needs to be scaleable with functionality that can be located throughout the system. In addition, an interchange color space with a wide color gamut and high bit precision is essential, as is the ability to store, process, and transmit multiple resolutions and bits. Lastly, protocols need to support information exchanges about devices and processing capabilities, and adapt to minimize transmission times and storage requirements.

References

1. *InterColor Profile Format*, version 3.0, 6/94, InterColor Consortium; Adobe Systems, Agfa-Gevaert, Apple Computer, Eastman Kodak, FOGRA, Microsoft, Silicon Graphics, Sun Microsystems, Taligent.
2. Continuous-Tone Colour Representation Method for Facsimile, NTT Laboratories, ITU-T Rec. T. 42, SG8, Q4, Group 3 Color Facsimile.
3. An International Standard for Color Facsimile, A. Mutz, *IS&T and SID 2nd Color Imaging Conf.*, 11/94.