Device Independent Color—Who Wants It?

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Abstract

The technology and architecture for using device independent color in documents is presented. The expectations and needs of the desktop users of color are examined and contrasted with the technical realities of digital color systems. Several major areas of color research are identified to address the problems of device independent color.

1. Introduction

The advent of desktop color management systems and PostScript level 2 printers offer the creators of color images and documents the opportunity to work in a device independent space. The technology to create, communicate and render device independent colors is technology well established in the industry and available in many current products.

While printing from scanned input and WYSIWYG color editing systems would, in most cases, benefit from device independent color, gamut mapping at the printer can be an unwelcome surprise to the creator. Today, graphics are generally conceived and described in device colors, with a confidence in a predictable appearance after the printing process.

This paper will discuss the values and pitfalls on operating in a device independent space and detail some of the color management sophistications that may be required for regular users to fully utilize device independent color.

2. Device Independent Color

Color is usually described in one of two ways:

a) device dependent description which gives the formula for producing the color of an object or a pixel on some device. Examples include the ink density on some printer, the digital value to put into the frame buffer of a workstation and the percentage of pixels to turn on in an ink jet device. The use of a device dependent color specification presupposes accurate knowledge of the printing device, in particular its performance when the image will be printed.

b) device independent description which gives the colorimetric coordinates describing the visual stimuli necessary to match the intended color. Colorimetric variables such as CIE XYZ and L*a*b* are examples of device independent color specifications. The printing or display of device independent color requires an accurate transformation to the parameters of the display or printing device.

Device independent color leads to an architecture for connecting scanners, printers and workstations. In this context, architecture means the segregation of function and the definition of interfaces. An architecture for device independent color is shown in Figure 1. In this arrangement, color devices (scanners, printers, and workstations) exchange data in device independent format, here CIE L*a*b*. The necessary transformations between their native, device dependent formats are performed before information is transmitted. One of the advantages of this system is that each device is responsible for its own accuracy. Addition of new devices to the system do not affect other computers or printers on the system. Color images and documents can be stored in a device independent manner and later be viewed or printed on any printer.

The architecture shown in Figure 1 is not the only one which implements device independent color, nor is it the only one which allows the easy addition of new devices. Its major strengths are the portability and easy reuse of archived document and the use of open standards including PostScript level 2.

3. Customer Expectation For Color

The concept of device independence is new to the graphics arts and not universally accepted. In the keynote speech at the IS&T session on Device Independent Color on Feb. 6, Professor William Schreiber expressed the belief that device independent color would never suffice for offset quality printing because of the fundamental differences between computer monitor color and the four color ink-on-paper processes. Thirty years ago, media guru Professor Marshall McLuhan came to prominence with the statement that *the media is the message.*

This tight binding of information presentation to its media is certainly true for the art world. A masterpiece is not available in oil, fresco and marble. The graphics arts have followed this tradition. Font design, the construction of graphics and the preparation of pictorial images have always been done with the destination print technology and the paper choice in mind. Although computerized composition and editing aids have been used for over twenty five years, they have been view as just that: devices to enhance the productivity of the skilled operator in producing better print material faster.

With the advent of desktop publishing coincident with the introduction of the Apple Macintosh in 1984, the computer was advertised as the document creation system. The screen portends the final print: *what you see it what you (will) get (WYSIWYG)*. Granted the screen did not have the color of paper and fonts were 75 dpi and the character fit was

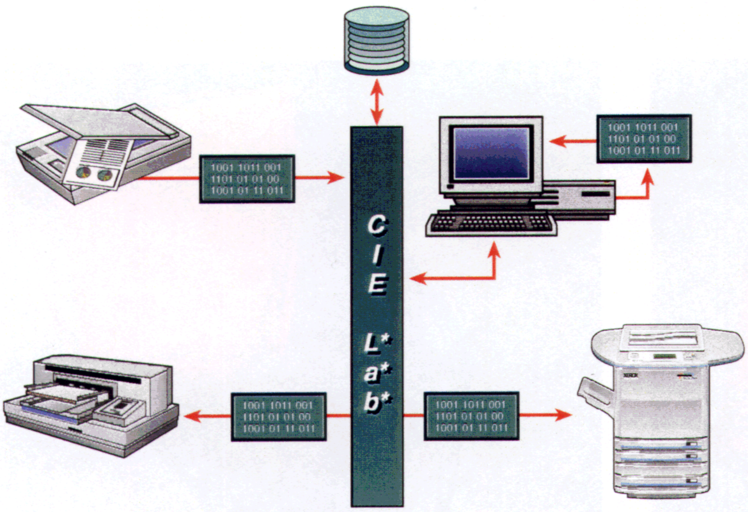

Figure 1. An architecture for device independent color wherein each input/output device is responsible for converting its native representation into a device independent representation, L*a*b*.

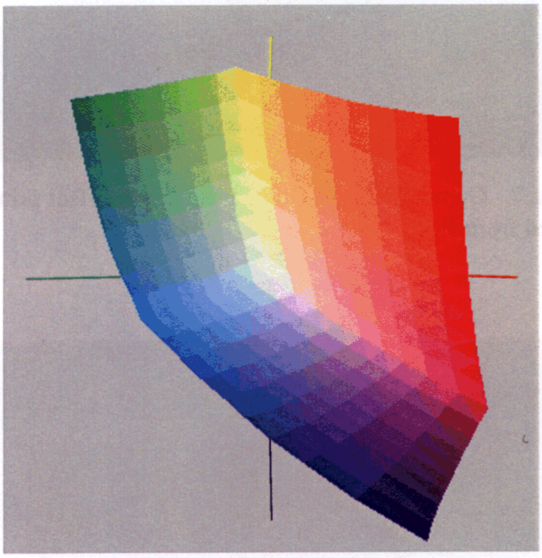

Figure 2. Color gamut of typical CRT monitor in L*a*b* view from above the white point.

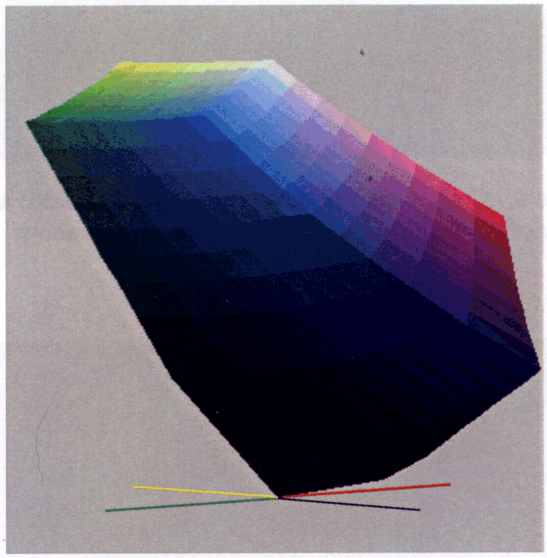

Figure 3. Color gamut of monitor viewed from side

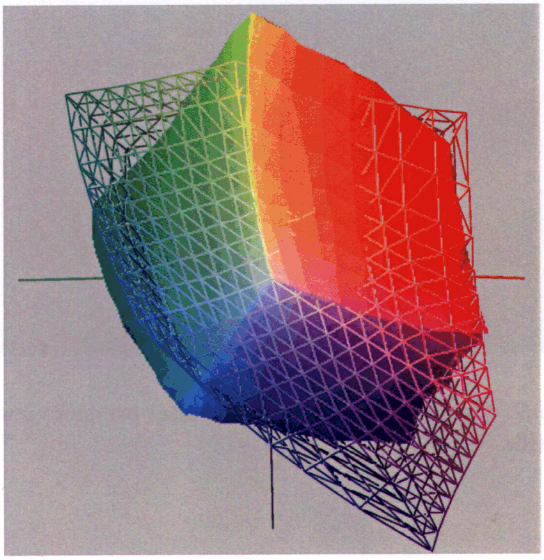

Figure 4. Color gamut of monitor (mesh) and gamut of Color Laser Printer (solid)

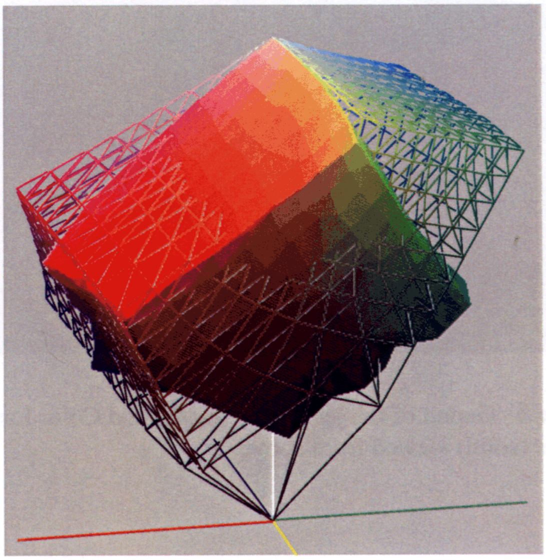

Figure 5. Side view of monitor and printer gamuts

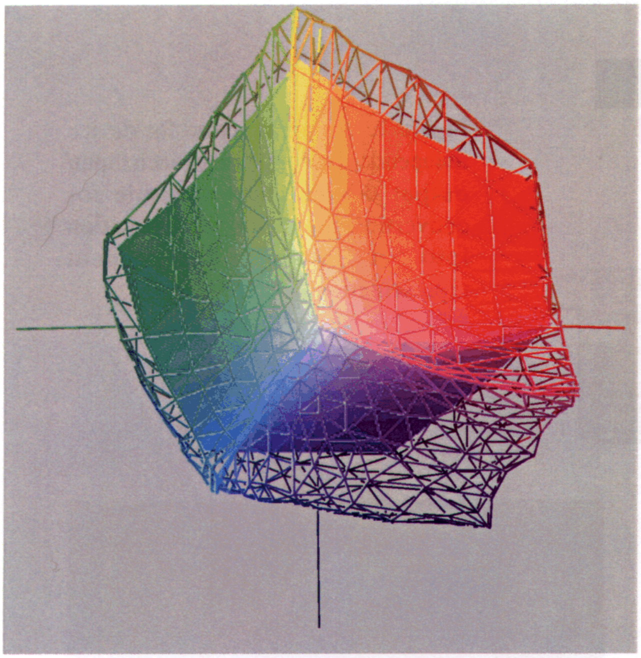

Figure 6. Color gamut of color Laser Printer (mesh) and gamut of typical offset printer (solid) view from above

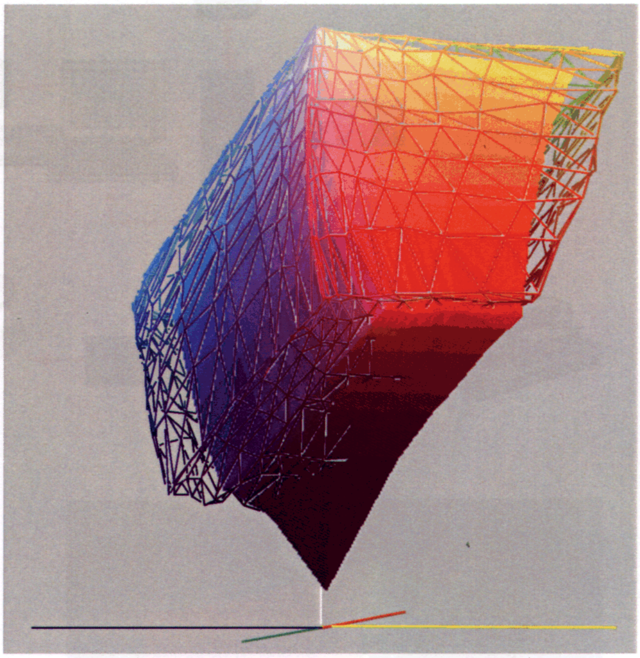

Figure 7. Gamut of Laser Color Printer and offset printer viewed from side

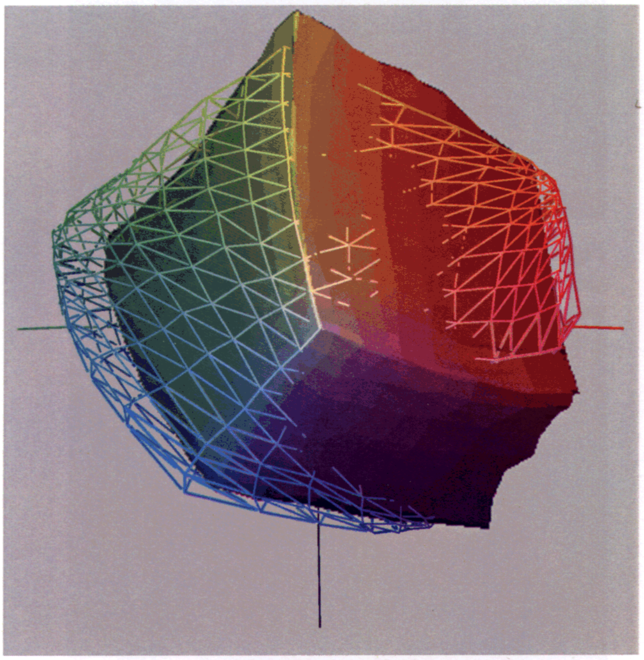

Figure 8. Gamut of ink jet printer (mesh) and Color Laser Printer (solid) viewed from above

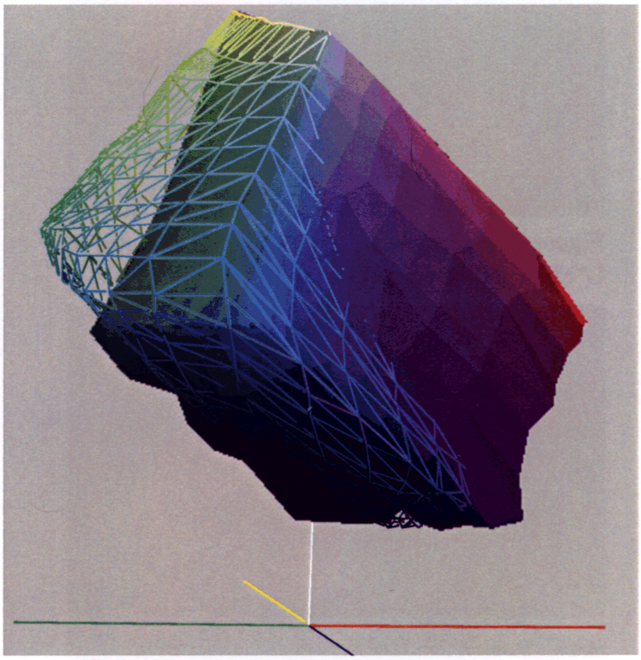

Figure 9. Gamut of color ink jet and laser printers viewed from side

crude at best, the line breaks and the layout matched the final print, that final print only looked better than the screen version.

It seemed that all the compositional details could be decided on the computer without reference to a test print. That is the big promise of WYSIWYG. With the total dominance of the desktop world by Microsoft Windows and Macintosh and their clones and the popularity of color displays and color capable desktop publishing software, everybody has the opportunity to get into color document creation.

4. Customer Needs in Color

The customer needs in color are only subtly different from his expectations. The first need is *no surprises color*—even though the printed color may not precisely match the display or the scanned-in image, even though the color laser print is not the *same* as the offset run, the customer is neither surprised nor disappointed.

A second clear need is for the color management to be *user friendly*. In this case, that hackneyed phrase translates to an effective hiding of the technology, to the elimination of the adjustment knobs found on graphics arts scanners and editing workstations and their software equivalent—sliders and buttons. Just as the bank of typographic editing keys found on the ATEX terminals have given way to a few pulldown menus, simple color controls (or better yet no controls) are needed. A corollary to user friendly is support for progressive learning: the ability for more and/or simpler control as the user becomes more expert with the system and the technology.

The final customers requirement for color systems is that the output image or document be archival and portable. The large investment in color documents demands that the document print on more than the local printer and that, when it is recalled from storage at some later date, the colors are as originally intended by the author. Device independent color is taken as the natural answer to this requirement.

5. Technical Reality of Color

The technical reality begins with mindset with which the desktop world looks at and describes color. Figure 2 shown the color gamut of the typical display. This is the usual 2D projection of the L*a*b* presentation of the CRT gamut. Contained within this colored egg viewed here from above the white point are all the colors that can be produced on the CRT. It is very instructive to look at this figure from the side as shown in Figure 3.

The first problem with WYSIWYG color is shown graphically in Figures 4 and 5 where the CRT gamut is shown in mesh superimposed on the solid gamut of a Laser Color Copier/Printer. When viewed from above, they look similar, but the side view shows that many bright saturated colors on the CRT that cannot be printed. In other words, there are colors seen on the CRT that cannot be obtained on the printer. And conversely, a lot of the colors produced by the printer cannot be seen on the CRT.

All printers do not have the same range of colors to chose from in rendering images. Figures 6 and 7 show the meshed Color Laser gamut overlayed on the gamut found in offset printers, here represented by the Kodak Approval proofing system. The Laser has a slightly greater color range in all regions except darkest regions where the greater Dmax of four color offset breaks through the Laser Xerographic range.

An ink jet printer using special coated ink jet paper has a very different character as shown in Figures 8 and 9. Extended green performance in the top view is seen to be in the lighter, saturated colors. The set of colors common to both printers is significantly less than those available to either technology alone. The laser printer has more dark reds and blues. When the ink jet is used on plain paper, the gamut shrinks, particularly in the lower region.

On the desktop, colors can be defined in a bewildering number of ways: the basic RGB, the intuitive HSV, the device specific printing inks CMYK, and more recently the device independent L*a*b*. Many applications simply offer a visual palette for the creator to select from. Through the desktop is a heterogeneous, standards averse place, it is not necessarily inaccurate. The measured colors of the Aldus Persuasion 2.1 color palette display on a self-calibrated SuperMac monitor were compared to the PostScript definitions sent by the application to printer and found to have an average L*a*b* error of 3.1, most of that attributable to dark colors which cannot be displayed in a moderately lit room.

For many of today' s color users, the greatest problems do not arise from the differences in color perception on self-luminant displays and subtractive printing processes nor in the differences in printer gamuts. The most difficult problems to solve come from the many transformations that go on between the application and the printers: the conversion from the application's color space and the desktop standards of Apple Quickdraw or Microsoft GDI, the various device profiles used by the application and the print driver in preparing the PostScript definition of the page to be printed, and finally the decisions made by the printer in preparing the device dependant image representation. These transformations occur at different places in the software infrastructure, and are often made by modules that do not have a consistent view of the problem.

These problems are not solved by color science or technology but by coherent actions by application and operating systems vendors. Actions such as the ColorSync standard are directed to solving this type of problem.

The technical challenges for device independent color come in three areas directly related to the print process itself which are often overlooked by color scientists:

1) determining the gamut mapping intent
2) developing the black printer
3) compensating for process shortcomings such as dot gain and trapping

As shown in the figures, a many colors can be requested of a printer that it cannot really print. The approximation can favour lightness or saturation or the whole input color space can be squeezed to fit into the available color gamut of the printer. Present desktop applications seldom offer the user the choice of approximations and, when specified, there is no standard way to send this information to the printer.

Black(K) is used in addition to CMY to render color to reduce ink thickness, to avoid registration errors when printing black text, and to more consistently render near neutral grey tones. Its use is very much an art and depends subtly on the image content. An algorithm to produce the suitable CMYK from a CIE color is a major challenge. For black text on a white background, full K with no CMY is used, while the black borders on a pie chart are printed in CMY with little K to avoid the unintended white drop shadow caused by misregistration. Each type of printing (laser xerographic, ink jet, offset) uses the K ink differently to solve their specific process problems.

The final device dependent problem arises at when two colored regions abut. For offset and laser refer to the trapping problem while for ink jet attacks inter-color bleed. In both cases, the the rendering of the pixels near the boundary are modified to minimize process-related defects in the appearance of the final printed page.

In the these last two cases, the inks laid down are not simply related to the color in the image but are determined by special needs of the process. Traditionally, many of these modifications are inserted into the image early in the creation phase where the spatial extents of objects and the design intent of the artist are clearly known. This information is clearly goes beyond device independence.

6. Conclusions

Device independent color has the potential to be of great value the creators and users of color documents. The successful printing of device independent color presents many interesting and meaningful technical challenges to imaging scientists, computer systems architects, and printer designers. These challenges include systems for capturing and communicating the color intent in a document, better perceptual models to enable the adjustment of the image to preserve those intentions under differing viewing conditions, and methods for fully utilize the gamut of each printing technology.

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