Integrating Color Printers into Color Systems

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Introduction

Color printing has been around for a long time. Only in the last few years have electronic means been available to print in color at quality levels that begin to compare with commercial processes. With the advent of these new and high quality imaging devices, color management has come to the forefront as important technology. Several years ago several people, including the author, worked on color management technology. In the mid 80's, however, applications supporting color were few and far between and color management was considered only by the technically curious. This paper will review the aspects of color printers that are important in their integration into color systems.

Color Printing

Color printers are one of many devices that a color management system must properly integrate. However, many devices such as displays and scanners utilize additive color to achieve their end results and hence and are less problematic to integrate. Printers utilize the subtractive color model to realize their output. For many reasons, subtractive color is more difficult than additive color. References 1, 2 and 3 can be used for more information on color systems. Let us now look at a typical printer hierarchy to assess integration issues. Figure 1 shows a printer block diagram that is useful in our discussions.

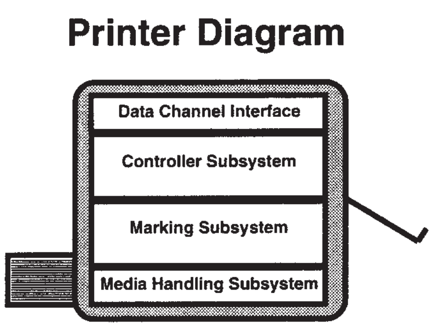

Figure 1.

In integrating a color printer into the system we must decide how each of the printer system blocks shown in Figure 1 impact or are impacted by integration. Each module provides some control or modification of the input data so that the printer marking system is presented with the most desirable data set. Let us look at each module or subsystem to see if it has any effect or provides any differentiation in the color system.

The first module is the data channel interface. This is the interface that allows us to deliver data from the "host" or data generator, most commonly a personal computer, to digital data buffers in the printer. This interface does not and probably should not provide any data mapping and hence can be quickly dispensed with as far as needing to be specifically color savvy. In the most simple form this interface could be Ethernet, AppleTalk, etc. Clearly the data will have structure associated with it but this structure is most important to the modules below the data channel interface.

The second module, the controller, is a key subsystem. Here, the data that has been sent to the printer must be interpreted and often "rendered" in the appropriate way to permit the printer to produce the desired results. Currently, there are two key page languages in use. The first is Hewlett-Packard's PCL now at level 5C which includes color. This language is on more monochrome printers than any other. The other language is PostScript® from Adobe Systems. The original PostScript referred to now as Level 1 contained no color calls but was later modified to provide particular calls such RGBSetColor, etc. Such a call would take a three byte color specification in RGB and produce the appropriate CMY and/or K bitmaps for the printer. Such a scheme is useful but does not permit good color management since visually appropriate color spaces such as CIE are not used. Level 1 was replaced with Level 2 nearly two years ago and contains absolute color spaces such as CIELAB, etc., although surprisingly not CIELUV. Therefore, the controller page description language or PDL must interpret the data received via the interface in such a way that the printed results have the closest possible relationship to the colors requested. This is easier said than done.

How does the controller know what to do with the data? Typically, the controller is either fed preprocessed data from the host or is fed with high level calls that it must interpret in the appropriate way. Both schemes are practiced today. The author prefers putting more processing in the controller rather than the host but space does not permit addressing the importance of that issue here. If the data channel receives a request to print a CIELAB color patch of $L^* = 50$, $a^* = -44$ and $b^* = 24$ for example, the controller must know what to do to get this on paper. How does the controller produce the correct signals to the marking engine? To generally answer this question, we must briefly look at the printer technologies.

First, one can either produce printed results using binary or grayscale methods. Binary printing is typical of conventional commercial ink-on-paper where one either has a given amount of ink depth or not. It is either "ON" or "OFF." Where marking occurs, the volume of marking material per unit area is constant. Secondly, printers can operate in a way that produces a variable amount of

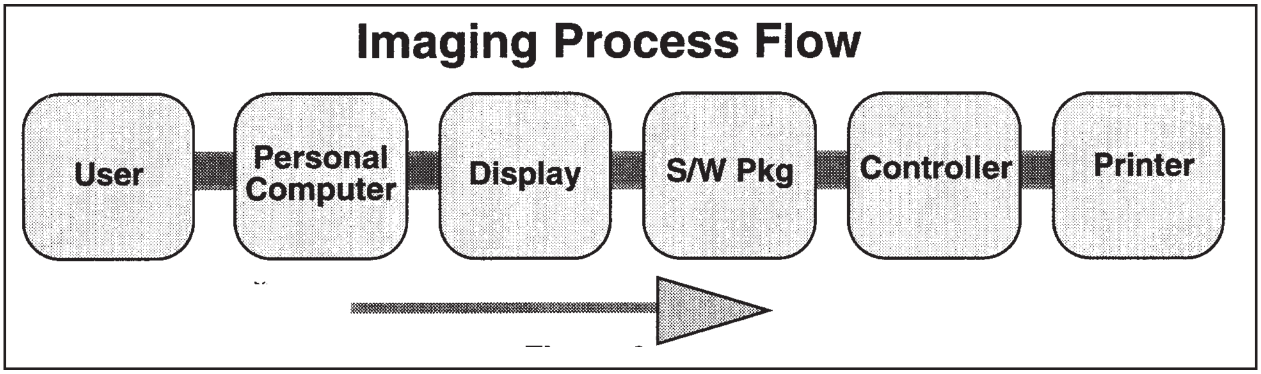

Figure 2.

colorant volume per unit area. Color printer technologies fall into four basic categories. These categories are electrostatic, ink jet, thermal and photographic. Depending on the printer technology, the controller must prepare a "bit map" that has been properly patterned via some form of halftoning or "pixel map" to realize the correct output from grayscale printers. Furthermore, drivers in the host send an image to the printer (controller) for printing sometimes with halftone patterns specified and sometimes not. Also, in some cases, halftone specifications are sent, only to be overridden by the controller because the printer uses a default or pre-programmed halftone or because the printer is a grayscale printer and does not halftone at all. The user is often confused and sometimes confounded by the arcane interactions of drivers and controllers.

Therefore to integrate printers, especially color printers into systems, proper division of labor and minimizing confusion is required. A typical imaging path might look like Figure 2.

Integrating a color printer into the system involves attention to all of the components shown in Figure 2. The user selects a color or colors by interacting with the PC. The display must render the user input in such a way that the screen spectra emitted provide a close visual/appearance match to the desired color. The color on the display is often chosen via a color "picker" or via software application-running on the personal computer. When the user is satisfied with the screen results and wishes to print the same color, the computer and application software via a driver send the color specification to the printer. While this may be obvious at first look, the interaction is often not that clean.

Often the driver modifies or translates the requested color into an imaging "call." Until recently, almost everything in the imaging chain did something to the data that was important from the perspective of the individual creating that particular part of the chain. Software enhancements and extensions such as Apple Computer's ColorSync®, EFIColor® and Kodak ColorSense®provide a methodology for controlling this process. To most conveniently and sensibly integrate a color printer into the imaging chain, the vendor or equipment provider should enable dealing with the printer at as high an abstraction level as possible. PostScript Level 2 is one such abstraction level although it does not support some popular color spaces. Apple's forthcoming QuickDraw GX® will provide another route that includes the ColorSync color management model supporting many color spaces.

Profiles that relate signals provided to the printer to device independent color space(s) are used in color systems like ColorSync to insure that consistent output is realized. Thus integrating a color printer should first deal with the abstraction level that the driver and application software will see. While it is more economical and faster to provide a simple low level interface, extensibility of the printer itself is much more difficult.

So far, we have talked only about sending data TO the printer. Quality integration of the printer also means getting data FROM the printer. This data can of course provide status, etc., but from the color perspective, why not have the controller provide the current calibration state to the host? Proper integration should therefore provide duplex communication capabilities of the printer. This is not done today with the possible exception of the Fiery®controller from EFI, Inc. While inexpensive printers cannot be electronics rich, departmental color printers such as the Canon CLC500, Xerox 5775 or 4700 and the Kodak 1550 have some electronic "smarts" to self calibrate. Such calibration is often densitometric not colorimetric. They will often set general copy quality but do not control it on a page to page basis. Recent tests by the author on various machines showed that page to page variations could be several ΔE units where $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$. It should be remembered that a ΔE of 1 unit is considered a Just Noticeable Difference or JND. Running 15 to 20 pages in a continuous mode through the printer yielded substantial variations that were color dependent. Some colors produced more variation than others. There was also noticeable startup variations. The printer itself must be responsible for controlling such errors. EFI, Inc. does provide a clever piece of software called Fiery Calibrator that will print a PostScript test sheet on the desired printer. This test sheet can then be measured with color instrumentation and the measured data automatically downloaded back to the controller for some adjustment of the output.

One must remember that all the user wanted was a number of prints that all looked the same. Proper printer integration should enable this end result with a minimum of fuss. Again, the printer should process the print job at as high an abstraction level as possible. The lower the level of abstraction at the printer, the more work that must be done by other system elements. Should every PC on a network be aware of all the nuances of controlling all of the color printers that can be addressed? How would the PC get access to all of the features. Most printer features are not obtainable via the interfaces. This weakness must be addressed and fixed so that the same device independent image can be sent to several printers with similar results provided the requested colors are within the printer's gamuts. The Fiery calibration capability would be greatly enhanced if the printer itself could provide a set of test data along the lines of the IT8 standards. The printing aspects of the controller and software could modify the data to realize consistent results during the day, etc. Printer calibrations that adhere to certain measurement standards assure that variations are not due mainly to methodology. Such standards and calibration issues could be customer transparent but are not insignificant if consistency and reliability are important.

Excellent printer integration is the only way to really make the demand color printing market grow the way it could. Color facsimile, now a limited capability from companies such as Sharp can be implemented network wide with proper integration. Should a user, for example, choose a custom halftone pattern, how will the system know what calibration or characterization to use? Rotated, novel, stochastic or other screens may be too numerous to have every possible profile/characterization existing at the user location. Clearly, the price of the printer must reflect the degree of integration but perhaps less than one might think. Silicon is continuing to improve its cost performance at an impressive rate. One might realize that until a short time ago, sending a PostScript or PCL file to a printer with multiple PDL capability required throwing a physical switch, changing a port, etc. Not a very convenient approach. Now, however, autoswitching controllers are available from printer vendors that detect the PDL data stream and automatically select the correct mode and software set required. Color printers must do the same and more.

Color printing is becoming commonplace and the market is growing strongly. Real growth in this market will require highly integrated peripherals of which the printer is key. The more of the imaging problem the printer is capable of solving, the more valuable it will become in the imaging chain. Somewhere the integration issue must be dealt with. Insofar as economically practical dealing with the problem at the point of use is better than at the point of data origin. Color printers should lead the way. This makes technical and most important of all, economic sense. Thus, integrating color printers into a system requires each system element to have some knowledge of the process. The more "smarts" in the printer the more universally it can be treated. Networked based printing could be considerably more complicated if a user in one geographic location must know all of the characteristics of a printer at another location in order to print a quality color document. Proper integration supports quality. Do you, the user, want to have every possible printer driver on your computer so that any printer you connect with on the network can be sent the proper signals? How would you know it is the current version? Would it not be better to have a printer that contained a high level of abstraction so that you could send only the image color specification and let the printer sort it out? High quality printer integration means minimizing the potential and actual issues the user must deal with. Amateur photography succeeded because Kodak, et. al., were able to hide the complexity behind a photo store counter or drive-up window. Users did not have to specify first developer temperature or bleach time, etc. Simplicity was and has been the key. Electronic color printers should strive for the same degree of utility. When that happens, strong market growth is assured.

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