Factors Governing Print Quality in Color Prints

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Introduction

The proliferation of the color printers in the computer world today introduced a huge numbers of prints available for everyone with good quality/cost performance ratio. With every new introduced model, it becomes more and more difficult to keep track of the differences between models and between performances, even if the comparison looks to a narrow price range. The printers are spread in a huge range in terms of price/quality area. On one side there are the ink jet printers, at a low cost but with a very high dynamic of the print quality in the recent years grouped at the "low end" users side, and on the other hand there are the costly and high quality offset printers required by the "high end" users side. In between, there are various color reproduction configurations at different cost/quality performance.

Looking for the optimum print quality, the visual differences are first encountered, then the time performance, services available, etc.

This paper emphasize the most important factors governing the print quality in color prints. These parameters are grouped an discussed in the next sections as follows: in section one the influence of the reproduction technology is discussed, followed by the colorant media interaction in section 2, geometric resolution in section 3, color resolution in section 4, color separation with black generation mechanism in section 5, and concluded with tone reproduction in section 6. Each section is illustrated with examples.

Reproduction Technology

Reproduction technology (dye sublimation, laser, ink jet, offset printing, etc.) represents the deciding factor that limits all further methods used to achieve a certain print quality. The printing resolution, the halftoning method, paper quality, and all other factors discussed in the next sections are limited and conditioned by the reproduction technology. For example, if a dye sublimation process is used, then this process can run only on certain paper type and quality.

From the user point of view, a fair comparison between the print quality of different reproduction technologies is difficult to be performed. Sometimes the general feeling looking at a printed page may conduct to a quality evaluation subjective but stronger enough to decide an user to choose a printing technology over another before considering other factors. From the point of view of a manufacturer, the technology is in general decided much earlier in the process of evaluation of print quality.

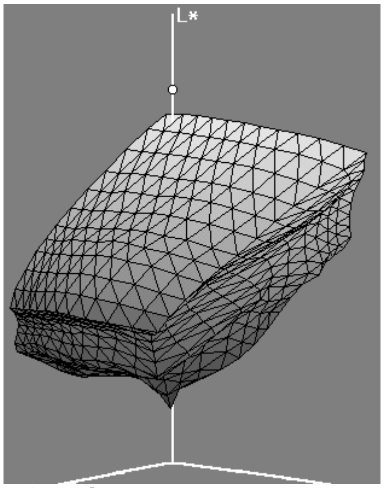
The range of colors that a color device can reproduce (referred usually as the device gamut) is one measure to compare the reproduction capability of a printer. The color gamut of a device is often used to compare different reproduction processes. Usually, the device gamuts are represented and compared in device independent color coordinate systems, as CIELAB or CIELUV or XYZ. A chromatic comparison can be achieved also in the 2D CIE chromaticity diagrams, with the limitation that this representation is not able to show the differences on the achromatic colors. The differences between different technologies can be quite significant concerning the maximum black that can be rendered on certain media and that are not visible in a 2D chromaticity diagram. This is why we will use here only the 3D gamut visualization that can give a more complete view of the behavior of a printing devices. A tool developed using the method presented in [1] is used to represent and compare the printing device gamuts.

Figure 1 is showing a comparison between the gamut of a Color Laser Writer 12/600 PS (laser printer) and the Color Style Writer 6500 (ink jet printer). It can be observed that for plain paper from where the measurements were taken, the Color Laser Writer shows a wider gamut with higher density at the full saturated colors. An intersection of the gamuts illustrates the differences between gamuts. Further discussions will be carried out concerning gamut comparison in the next sections.

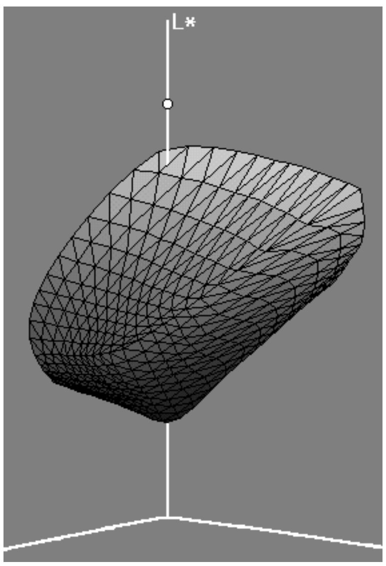
Colorant / Media Interaction

Colorant / media interaction (plain paper, glossy, coated, transparency, textile, etc.) determines the actual gamut of the colors that can be reproduced on a certain device.

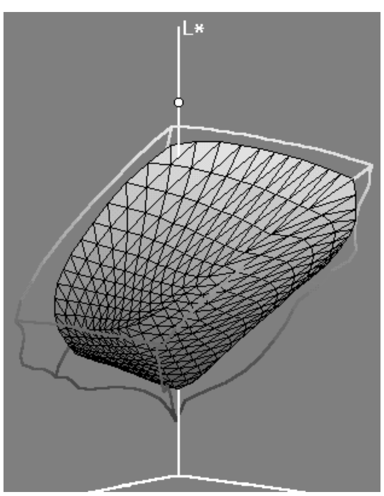
The influence of the media is crucial in achieving a high quality of the printed image. Certain devices can operate only on a very specific media, as is it was mentioned for dye sublimation devices. Other devices as the ink jet printers can print on a variety of media from plain paper, coated paper to high quality photographic paper. The difference between print quality for these devices can be significant. The substrate properties determines how the ink is absorbed, influencing the dot gain (optical dot gain, and the physical dot gain) and the density levels. Significant efforts have been made in order to quantify and model the effect of the dot gain [2,3,4]. The influence of the dot gain is compensated by a proper tone reproduction curve as it will be discussed in the last section in this paper. The properties of the substrate determines also how much ink can be deposited on the paper that in turns influences the maximum density levels achievable on that media. The density levels determines the shape and the size of the color gamut that in turn influence the quality of the printed result. Using a media that is able to absorb uniformly the ink, to limit the lateral dispersion of ink within the material and with a fine structure that limits the lateral light scattering within the material are another keys to achieve high quality prints.



(a) Color Laser Writer 12/600 PS

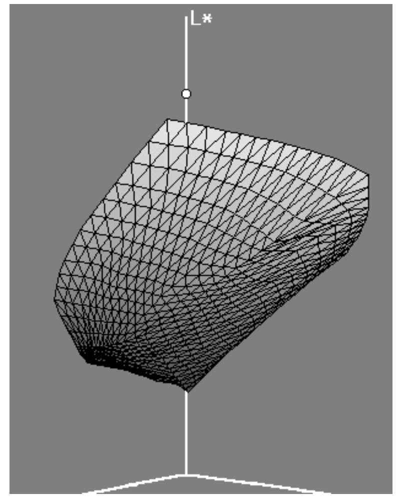


(b) Color Style Writer 6500

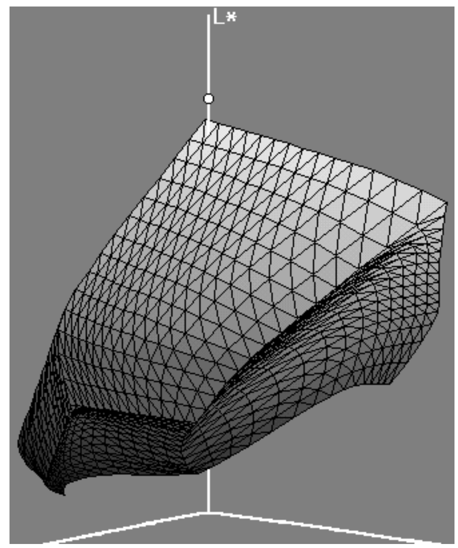


(c) gamut differences of (a) and (b)

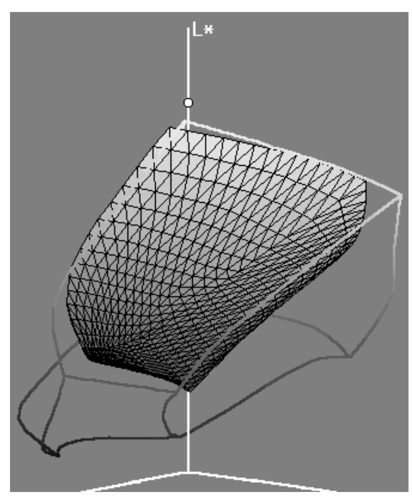
Figure 1. 3D gamut representation of a laser and ink-jet printers on plain paper.



(a) coated paper, best mode



(b) photographic paper, best mode



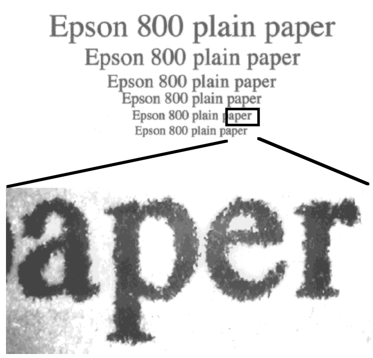
(c) gamut differences of (a) and (b)

Figure 2. Color Style Writer 6500 ink jet printer gamut on coated (a) and glossy paper (b) and their differences (c).

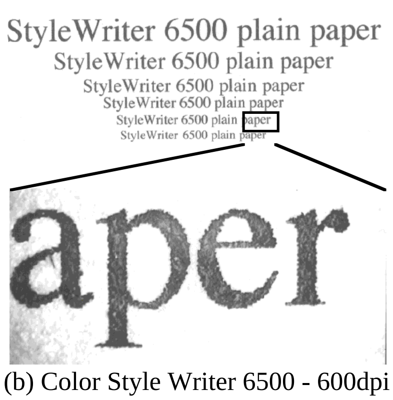
As an example, the figure 2 represents the gamut of a Color Style Writer 6500 for plain paper, coated paper and photographic paper. The maximum amount of ink is higher on the photographic paper than on coated and than on plain paper. Therefore, the photographic gamut is larger than the coated and plain.

Geometric Resolution

Geometric resolution dots/inch represents the maximum number of the smallest printer dots that can be printed per the geometric unit (inch). It is determined by the engine that is used to transfer the colorants to substrate but is also influenced by the media that receive the colorant. Controlling the dot shape, dot size and placement on the paper is the key to achieve the geometric print quality on the paper. Figure 3 shows the difference in print quality between prints on same type of material (plain paper) and for the same printing mode (best mode) for Color Style Writer 6500 and Epson 800 ink jet printers. Even if the Epson 800 works with 1440 dpi addressability resolution, the 600 dpi resolution Apple printer achieve a higher degree of control of the dot size and shape that creates a visual higher quality.



(a) Epson 800 - 1440dpi



(b) Color Style Writer 6500 - 600dpi

Figure 3. Two sample prints on same type of substrate (plain paper) and with same print mode (best mode) for 2 ink jet printers.

For ink jet printers, a higher quality in print results if the dot size is reduced to be less visible. Therefore, significant efforts have been made to achieve a higher degree of control on the amount of ink that is deposited on the substrate. Several definition may help in understanding the performance and limitations of such devices. A drop refers to the smallest amount of color of ink that can be deposited on substrate from the ink cartridge. A dot results by placing a cluster of drops on the substrate. A dot is formed of one or more of ink drops of each colorant. The recent progress in ink jet nozzle technology enables the new printers to control the amount of ink dropped on the substrate to a high degree [5] as it is shown in table 1.

Table 1. The evolution of the ink jet nozzle technology is reflected in the reduction of the smallest amount of ink that can be deposited on the substrate (ink drop). The numbers in the following table are expressed in 10-12 litters (picoliters).

Year:	1991	1995	1996	1997
Drops:	~80	~50	~30	~10

Color Resolution

Color resolution is usually dictated by the halftoning method and its parameters. These parameters are summarized below:

- amplitude modulation vs. frequency modulation
- large screening cells (good color quality & poor details) vs. small screening cells (low color quality & good details);
- interference between ink layers (moire, rosette);
- dot-on-dot, dot-off-dot color halftoning;

Color Separation

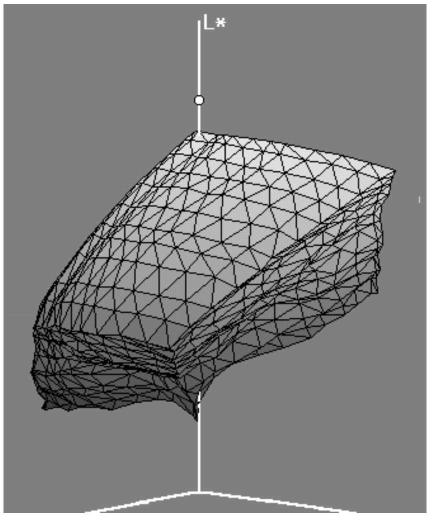
Separation is the process of conversion of the RGB components of each pixel in the original image in digital format to three (CMY), four (CMYK) or n components (ex: CMYK + Orange + green + spot colors) usually expressed as percentage of colorant; For four or more component printing process, the separation requires also a black generation procedure that is the key in reducing the coverage of inks for the printing surface, without sacrificing the quality of the color reproduction. Several techniques are discussed as: under color removal, gray component replacement, under color addition.

Figure 4 illustrates the differences between two black generation techniques combined with corresponding under color removal scheme. It is clear that the black generation in figure 4(a) display a loss of color rendition at high density, therefore affecting the color reproduction quality for high density region of the printed image.

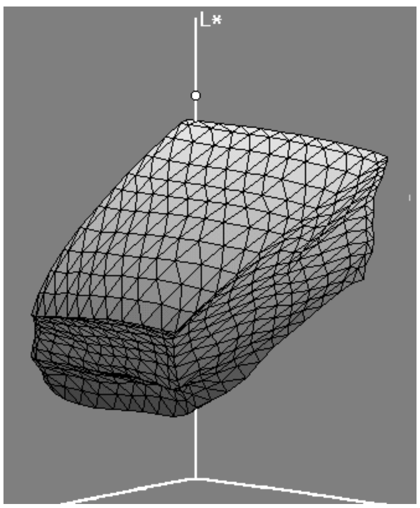
Tone Reproduction

Tone reproduction is the reproduction of achromatic colors. The achromatic colors are the one that give the general pleasant and natural aspect of the most photographic quality printed images.

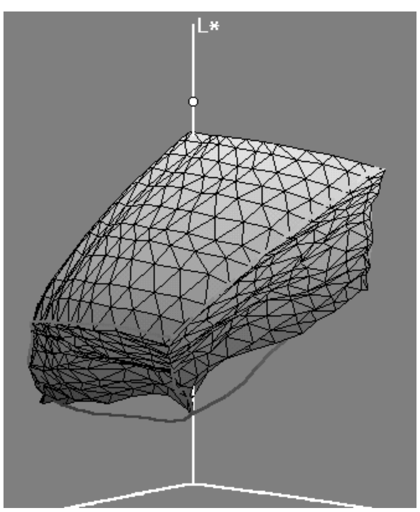
Usually, the ink/media interaction is compensated individually for each colorant by the tone reproduction curves (TRC). The colorants should be always considered in correlation with the media on which they are printed. Therefore, each media is associated with a set of TRC.



(a) poor black generation



(b) correction to the black generation (a)



(c) gain in gamut from (a) to (b)

Figure 4. Enlarging the gamut of a Color Laser Writer 12/600 PS printer through the black generation

Device Characterization and Calibration

Device characterization include all the factors that influence the print quality and that can determine the behavior of a color device in its nominal state. The compensation of the non-linearity of the real printers generally requires a relativelly large number of measurements of printed samples and an interpolation procedure [6] or more sophisticated analytical models (based on free form deformations [7], spectral description of color, etc.). In general, the characterization information of a color device is stored in a device profile. For compatibility across different computing platforms, the profiles are coded in a structure specified by International Color Consortium (ICC). In this form, the characterization data can be ported between color management systems or computer platforms, and enables a consistent specification of color independent on the computer system and color device.

Device calibration is the process required to re-adjust a device to a known state, that is generally the state in which the device was characterized. It generally requires less expensive equipment and much less effort than a characterization process, and is intended to be repeated whenever is required.

Summary

The progress of the printing technology is very demanding, requiring to find and adapt the traditional concept of printing to new possibilities that are opened by new media and new non impact printing technologies. This paper illustrated few aspects that affect the color quality of the printed images, but is just a start for a future study on the print quality. Further development and discussions can add new section to the paper and can point out other aspects that were not included here. However, several critical factors in achieving the desired print quality of color images are pointed out:

- the proper control of the drop size in ink jet is the key in achieving the right geometric resolution;
- black generation method is a key to achieve a larger color gamut;
- new printing media can increase significantly the quality of prints;

The paper illustrates all the mentioned printing quality factors with examples, giving the opportunity for the reader to compare and evaluate the contribution of each one in achieving the a certain quality at a given cost.

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