Image-designing and Color Management for Digital Still Camera and Printer System

Hitoshi Urabe, Makoto Tsugita and Kouji Ichikawa
Fuji Photo Film Co., Ltd., Saitama, Japan

Abstract

We will describe tone-reproduction and color-reproduction of newly-developed digital still camera, DS-505, and Pictrography 3000 system. The followings are main content.

(1) Comparison of Neugebauer's Q-factors of digital still camera and typical negative film: The ascending order of Q-factor is 3-CCD camera, 1-CCD camera and typical negative film.

(2) Aimed image-reproduction: The image, reproduced using professional-use negative and color paper, has been adopted as aimed image-reproduction. How to optimize various parameters to keep good image quality will be also described.

(3) Color management system: To keep good image quality and data-exchangeability, EXIF (Exchangeable Image Data Format), proposed to ISO/TC42/WG18, has been adopted. How to manage color quality parameters will be discussed.

Introduction

With progress in digital technology and the advent of the multimedia age, images captured by a variety of imaging devices are sometimes reproduced on a monitor and on hard copy at the same time, and also stored as the same file format. In this case, it seems desirable that both images formed on silver halide-based film and converted by a scanning device to a video signal, and those directly acquired by a video imaging device exhibit the same tone and color reproduction characteristics. For images from such dissimilar media and devices to be exchangeable with each other, there should be some agreement to be satisfied. As one step for attaining this goal, we conducted image reproduction design on a system combining a digital still camera (DSC) and a digital printer. This paper addresses the following three points:

(1) Spectral sensitivity evaluation for imaging devices, based on Q-factors;

(2) Tone/color reproduction design in a combination of a digital still camera and a digital printer; and

(3) Proposal for a standard video signal to realize device-independent color.

Spectral Sensitivity Evaluation for Imaging Devices, Based on Neugebauer's Q Factor

Spectral sensitivity is of critical importance for imaging devices. Unless colors (especially hues) of a subject were captured accurately by an imaging device, it would be quite difficult to correct them later on. The first step for device-independent color (DIC) is to capture hues accurately with the imaging device.

As a basic design guide, the spectral sensitivity is aligned to a color-matching function (a linear transform of spectral sensitivity of a human eye, as defined by the CIE (Commission Internationale de l'Eclairage). This is well known as Luther's criterion. As an index indicative of how closely the designed spectral sensitivity is aligned to the color-matching function, a Q-factor proposed by Neugebauer[1] is available. We calculated Q-factors for typical silver-based film and various types of DSC. The results are presented in Table 1. For spectral sensitivity of a human eye, its Q-factor is equal to 1.0.

We concluded the followings.

I. These results indicate that the 3-CCD camera captures images, with exceptionally high color fidelity.

II. In general, the 1-CCD camera has a greater Q-factor with an additive color filter than with a subtractive color filter.

III. The typical color negative film produces satisfactory color reproduction, even though its Q-factor is not much higher, mainly for two reasons. First, for silver halide-based film, chemical color processing (i.e., an interlayer effect) allows for enhancement of saturation. Second, spectral colors that call for a higher Q-factor to achieve high color fidelity are very few in an actual scenes.

IV. There is a difference in color where the DSC and silver-based film offer high color fidelity. Film exhibits poor performance at cyan on the Macbeth color checker, whereas the digital camera is poor at bluish green.

Image Design for Digital Still Camera and Digital Printer System

Kodak announced Photo CD, a file format for images scanned from silver halide-based film. With Photo CD, a scene is shot as defined in CCIR-709 and converted to

Table 1. Q-factors for digital still cameras and silver halide-based film

	Red	Green	Blue
3-CCD with dichroic prism	0.87	0.94	0.9
1-CCD with additive *R, G, B) color filter	0.97	0.73	0.64
1-CCD with subtractive (C, M, Y) color filter	0.61	0.69	0.58
Typical color negative film	0.49	0.87	0.63

a YCC signal and compressed as defined CCIR-601 for recording in the Photo CD format. Photo CD has its aim to provide colorimetric reproduction of colors of a daylight scene on a color monitor display: as such, image data on the silver halide-based film must be converted in such a manner that its colorimetric reproduction is produced on a color monitor. The intention of this design philosophy seems to maintain the afore-described compatibility between video imaging and film-based photography.

For a reproduction target on a monitor, we also adopted a concept similar to Photo CD (to provide colorimetric reproduction of a scene brightness ratio on a monitor) (see Figure 1). This is important from a standpoint of compatibility with existing video camera output signals.

For an image reproduction target for hard copy from a digital camera, we adopted tone characteristics and color preferences achieved with a combination of professional-use negative film and color paper. This is because the digital camera designed is expected to find main use in professional and industrial applications.

As a result of the development efforts with this image reproduction target in mind, we came up with a digital card camera, FUJIX DS-505[2] and a digital image processor, FUJIX DI-500, both unveiled in February 1995. We implemented parameter design on a system (Figure 2) comprised of the DS-505 and DI-500 in conjunction with a silver halide-based photographic digital printer, FUJIX Pictrography 3000, in such a manner that prints can be produced to meet the afore-mentioned image reproduction target.

It is, of course, possible to produce prints on the Pictrography 3000 from a personal computer via a PC card/PC card reader or via an image transmission system, even if the DI-500 is not available. With the DI-500, however, prints of much superior quality could be obtained, because manipulations are added for approaching this overall image reproduction target.

Print quality-related functions of the DI-500 include print tone correction, color correction, and sharpness enhancement. Print tone correction downloads into a user LUT area of the printer (FUJIX Pictrography 3000) via a SCSI a LUT for translating an image having a tone suitable for display on a color monitor to an image suitable for reproduction on print.

The color correction function downloads, via a SCSI, correction factors necessary for color masking calculation that is done in the color printer to achieve the target color reproduction described below.

Sharpness enhancement is performed independently in the DI-500, so that sharpness correction is done according to print size. Indeed, sharpness levels are user selectable in four steps, including no sharpness correction. Consideration is also given so that noise portions of an input signal will not be enhanced carelessly.

Those three functions are implemented so that processing suited for all professional input devices that are and will be available from Fuji Photo Film will be performed in compliance with *Exif* tag information, which will be described below.

Overall tone characteristics between the subject and hard copy are set with approximately g = 1.2 for a subject which is darker than 18% reflectivity, and g = 0.9 or

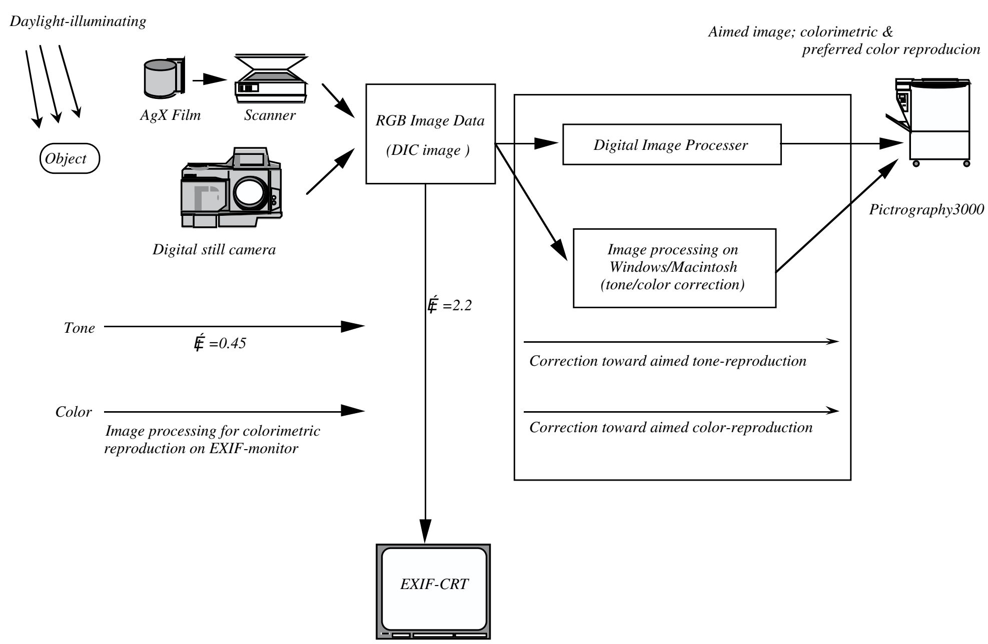

Figure 1. Image reproduction using standard (=EXIF) video signal

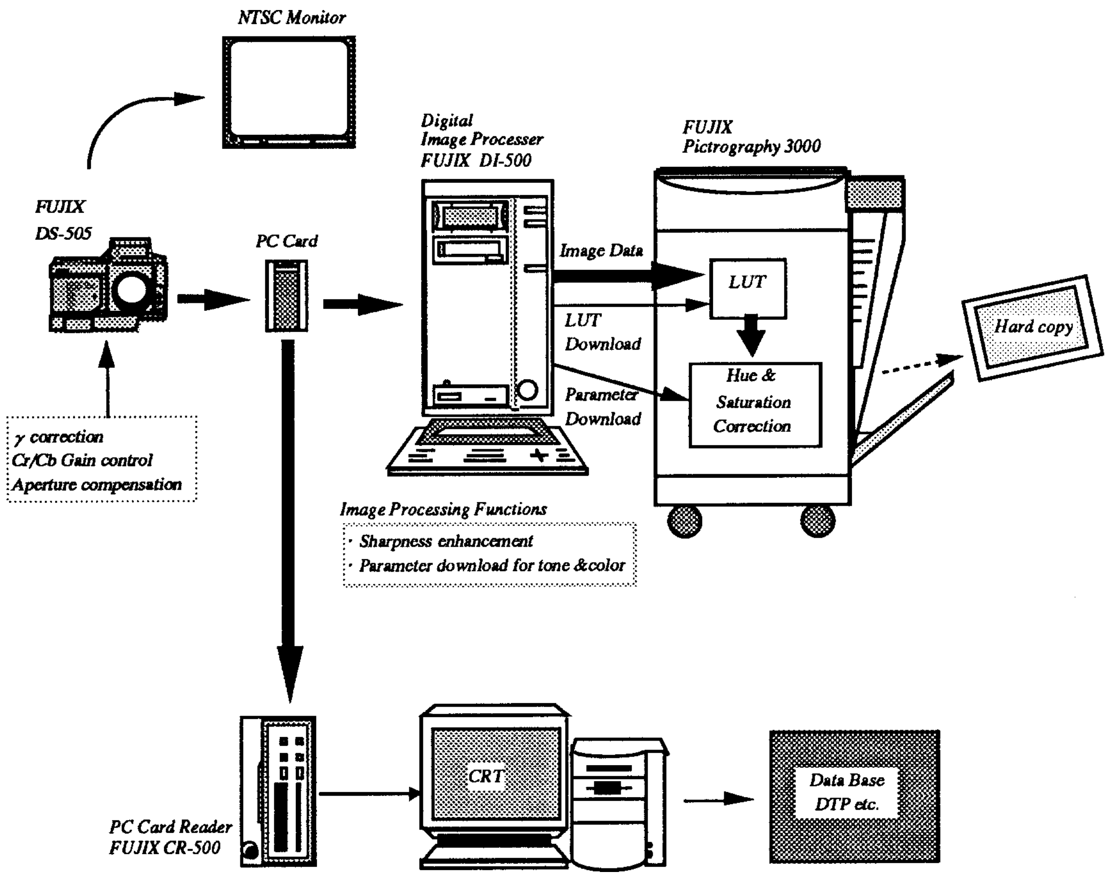

Figure 2. Image Processing in Digital Still Camera and Pictrography

less for human face highlights, thus yielding a marked difference from those of conventional digital camera/hard copy systems, which have an overall gamma of about 1.0, from highlight to shadow areas. This permits smooth reproduction of human flesh color, the most important subject, over a whole gamut from dark to light gradations, in spite of vivid, crisp rendering, as a whole, in comparison with conventional electronic imaging/hard copy systems.

For color reproduction, we intended to attain colorimetric reproduction between the subject and hard copy. Eventually, the design takes three factors into consideration: colorimetric reproduction, retention of tones for highly saturated colors, and reproduction of memory color for flesh tone. Consequently, a color difference on the LAB space between the subject and hard copy was about 8.7 (relative to Macbeth's 18 colors excluding gray).

Color Management System

With our sight set on the development of information infrastructure encompassing personal computers, which have been undergoing rapid proliferation and advancement, we have proposed a full-color image file format "*Exif*" (Exchangeable image file format[3]), which is stored on a PC card-based digital still camera and its related peripherals.

Exif is intended to offer an image file format that retains data compatibility and exchangeability between peripherals under the PC environments and is amenable to many applications. While reference should be made to the literature 3 for more detail, RGB color management information is focused here.

There are two concepts regarding how to define RGB colors: One scheme is to use specified values (e.g., CCIR-709). The other is to employ standard values for actual monitors. The former is adopted in Photo CD, while we employs the latter for the following reasons:

I. Although monitors are manufactured by various makers, the phosphors used in the CRTs have been boiled down to the same type (P22). In addition, color temperatures used hover around 9300K as a practical criterion. In other words, RGB colors and color temperatures are increasingly unified as practical criteria.

II. By using the practical criteria, direct-to-monitor output becomes possible. If exact output by use of a specified value is expected, it must be converted to practical criteria, resulting in an unreasonable burden imposed on the processing system.

The monitor RGB colors we employed are as follows (note that values set forth in the catalog of Sony's monitor are used):

Chromaticity	Red	Green	Blue
x-coordinate	0.625	0.28	0.155
y-coordinate	0.34	0.595	0.07

By employing these monitor RGB primary colors, together with a color temperature of 9300K (Wx = 0.2831, Wy

= 0.2970) and gamma characteristics (CCIR-709), one can identify a color. That is, a XYZ-space signal can be determined from the input RGB signal. The resulting RGB video signal is a device-independent color signal. The output of our DSC is based on this standard signal. That implies that if our standard signal is used, it could be easily converted to a profile of the International Color Consortium (ICC).

The standardization process described so far is important to make the RGB video signal device-independent; but it is far more critical for a digital still camera that cannot use any ICC profile because of its memory limitation.

Summary

As one step in the process of building an arrangement that permits interchange between an image scanned from silver halide-based film and an image directly acquired from video, we performed image reproduction design for a digital still camera and a digital printer. Meanwhile, we made spectral sensitivity evaluations on various imaging devices and defined a standard video signal that is both suitable for practical monitors and amenable to device-independent color.

References

1 H. E. J. Neugebauer: "Quality factor for filters whose spectral transmittances are different from color mixture curves, and its application to color photography", *J. Opt. Soc. Am.*, Vol. **46**, No. 10, October 1956, pp.821-824.
2. M. Takemae et. al., "The Development of SLR-type Digital still camera", *IS&T's 48th Annual Conference Proceedings*, pp.414-417.
3. M. Watanabe et. al., "Signal Processing LSIs for High-Resolution Digital Card Camera DS-505/DS-515", *IS&T's 48th Annual Conference Proceedings*, pp.421-424.