

Color Transformation to Photography Tone in Digital Camera Printing System

Takashi Watanabe, Ryo Kuroda and Yasushi Hoshino
Nippon Institute of Technology, Saitama, Japan

Abstract

Recent progresses of digital camera system are very rapid and the image quality of the system is improved very much. On the other hand, conventional silver halides photography is one of important color image recording system. We extract the characteristics of the conventional photography and simulate the characteristics in the digital camera system. Simulation method is formulated and is applied to the photography tone transformation. It is confirmed that photography tone image is printed in the digital camera system.

Introduction

Recent advances of digital technologies are rapid. In the field of photography, digitization by photo-CD and digital camera is progressing with the advance of computer.[1] New area of usage with computer is born and is expanding. The expression of color is one of important factors in imaging system.[2] There are several methods of color expression; colormetric matching, perceptual matching and so on. The conventional photography by silver halide is most widely used and is very important technology in imaging system. So, the simulating color tone of the photography become one of important applications in digital system. We proposed the calculation method of transformation to photography tone.[3]

In this report, extraction of characteristics of photography tone is improved and the method of transformation to photography tone is also improved.

Experiment

1) Characteristics of Photography

Color patches are prepared by ink jet printer. The color patches are taken on nega film by camera. The film is developed and then printed on photographic paper. The print is measured by colorimeter. The color values of the original color patches and the printed one are tabled, and are relationed by mathematical method such as fitting.

Instruments and Material

Single-lens reflex camera : OLYMPUS L3
Film : Three kinds of negative films from the different manufacturer (sensitivity : ASA100)
Color patches : 216 color (prepared as RGB data in computer), Grayscale 18 level
Colorimeter : MINOLTA CM-2022

Condition for Taking Photo

Illumination condition : light box (fluorescent lamp D65)
Distance between camera and color patch°G500mm
Aperture : 5.6
Shutter speed : 1/45 second

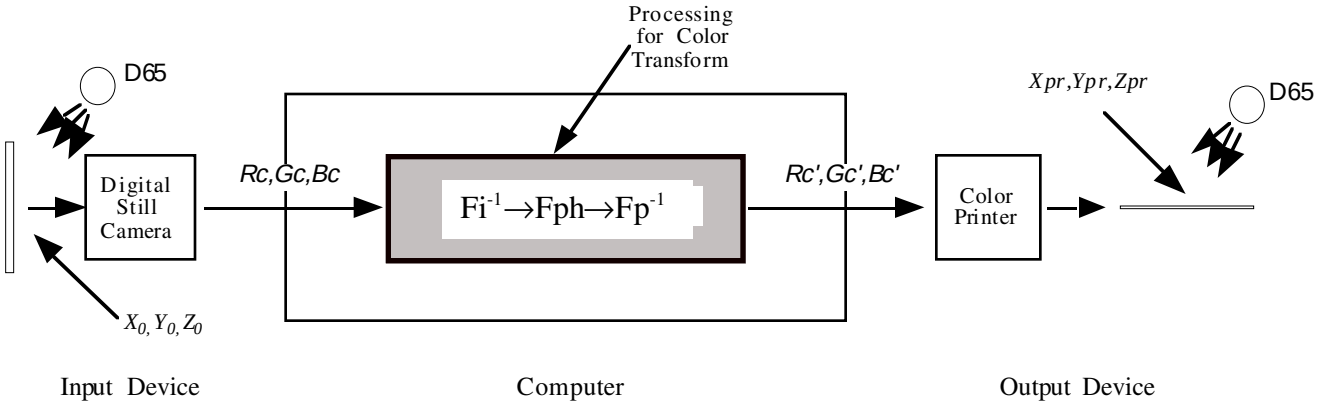

Figure 1. Data flow of transformation to photography tone in digital printing system

2) Digital Camera System

Data processing flow in this experiment is shown in Fig. 1.

schematically. Color image sample is illuminated by D65 light. The image is captured by digital input device and becomes to digital data.

Digital Input : Digital Camera (KODAK DC260Zoom)
Printing System : Inkjet Color Printer (EPSON PM2000C)
Printing Paper : EPSON Photo Quality Glossy Paper
Computer : APPLE PowerMacintosh7300/180
CRT (APPLE AppleVision 1710 Display)

3) Formulation

In this session, we summarize the general formulation of the transformation to photography tone. We define three functions expressing the relations between data.

(1) Digital still camera

The function ***Fi*** expressing the characteristics of digital still camera is defined,

$$(Rc,Gc,Bc)=\boldsymbol{Fi}(Xo,Yo,Zo), \quad (1)$$

where *Rc,Gc,Bc* are the data captured into computer and *Xo,Yo,Zo* are the XYZ value data of color image. Both data correspond to same point of the image and the Eq.(1) is defined to be satisfied at the every points of the image.

(2) Color printer

The function ***Fp*** expressing the characteristics of color printer is also defined as,

$$(Xpr,Ypr,Zpr)=\boldsymbol{Fp}(Rc',Gc',Bc'), \quad (2)$$

where *Rc',Gc',Bc'* are the data transferred to the color printer and *Xpr,Ypr,Zpr* are the XYZ value data of the print-out by the printer.

(3) Taking photo

The relation function ***Fph*** between original image and its photo print is expressed,

$$(Xph,Yph,Zph)=\boldsymbol{Fph}(Xo,Yo,Zo), \quad (3)$$

where *Xo,Yo,Zo* are the XYZ value data of original color image and *Xpr,Ypr,Zpr* are the XYZ value of its photo print.

(4) Transformation to photography tone

The XYZ value *Xpr,Ypr,Zpr* corresponding to photo print is necessary to be printed by printer. Therefore, the transformation to photography tone is expressed,

$$\begin{aligned}(Xph,Yph,Zph)&=\boldsymbol{Fp}(\boldsymbol{Fp}^{-1}(Xph,Yph,Zph))\\&=\boldsymbol{Fp}(\boldsymbol{Fp}^{-1}(\boldsymbol{Fph}(Xo,Yo,Zo)))\\&=\boldsymbol{Fp}(\boldsymbol{Fp}^{-1}(\boldsymbol{Fph}(\boldsymbol{Fi}^{-1}(Rc,Gc,Bc)))),\end{aligned} \quad (4)$$

where $\boldsymbol{Fi}^{-1}(Rc,Gc,Bc)$ means the XYZ value of original image that corresponds to the data *Rc,Gc,Bc* transferred to computer, ***Fph*** means the photo print image of the original image, and $\boldsymbol{Fp}^{-1}$ means the data sent to printer by which data printer prints the photo print image. So, it is expected that photography tone image is printed by the digital still camera printing system by using Eq.(4).

Above discussion, we use the function as a sign of relating two sets of data. The method of relating is important problem. Usually, fitting and LUT (Look Up Table) are applied. In this study, 2nd order fitting method is used.

Result and discussion

1) Extraction of Photography

The measured results of original image (C, M, Y, CM, CY, MY) and its photo are summarized in Table 1. The plot on a*b* plane of the measured results are shown in Fig. 2 (a). The change of gray levels by taking photo is shown in Fig. 2 (b). It is seen that, by taking photo color gamut is shrunk and gray scale is transformed to S-shape (gamma is more than 1.). From the viewpoint of image processing, the area of high gamma is enhanced in density space. It is thought that the photography realized the optimized S-shape characteristics in the long improvement history.

Table1. The Characteristics of the Photography

Original Image	L*	a*	b*
C	64.54	-33.59	-22.47
M	53.01	75.04	-9.69
Y	87.61	-7.10	75.79
CM	22.73	33.84	-57.71
CY	56.86	-55.09	32.58
MY	49.76	68.56	45.45
Photography	L*	a*	b*
C	51.04	-28.75	-24.71
M	33.46	51.20	14.39
Y	68.33	5.69	72.98
CM	12.23	19.51	-37.01
CY	42.47	-42.77	26.09
MY	31.11	49.85	35.85

2) Extraction of Digital Camera

The characteristics of digital camera system are also examined. The characteristics are needed to transform the RGB data of digital still camera to photography tone. The original image (C, M, Y, CM, CY, MY) and its hardcopy printed by ink jet printer are measured and the plot of the measured value is shown in Fig. 3 (a). The gray level by digital camera system is shown in Fig. 3 (b).

3) Transformation to Photography Tone

In the digital camera system, transformation processing to photography tone is carried out by using Eq. (4). In the processing, 2nd order fitting *i*s applied. The values a*b* of transformed results of C, M, Y, CM, CY, MY colors are plotted in Fig. 4 (a). The gray levels are also transformed and its result is shown in Fig. 4 (b). From Fig. 4 (a) and (b), it is considered that the transformation processing to photography tone is accomplished in good approximation.

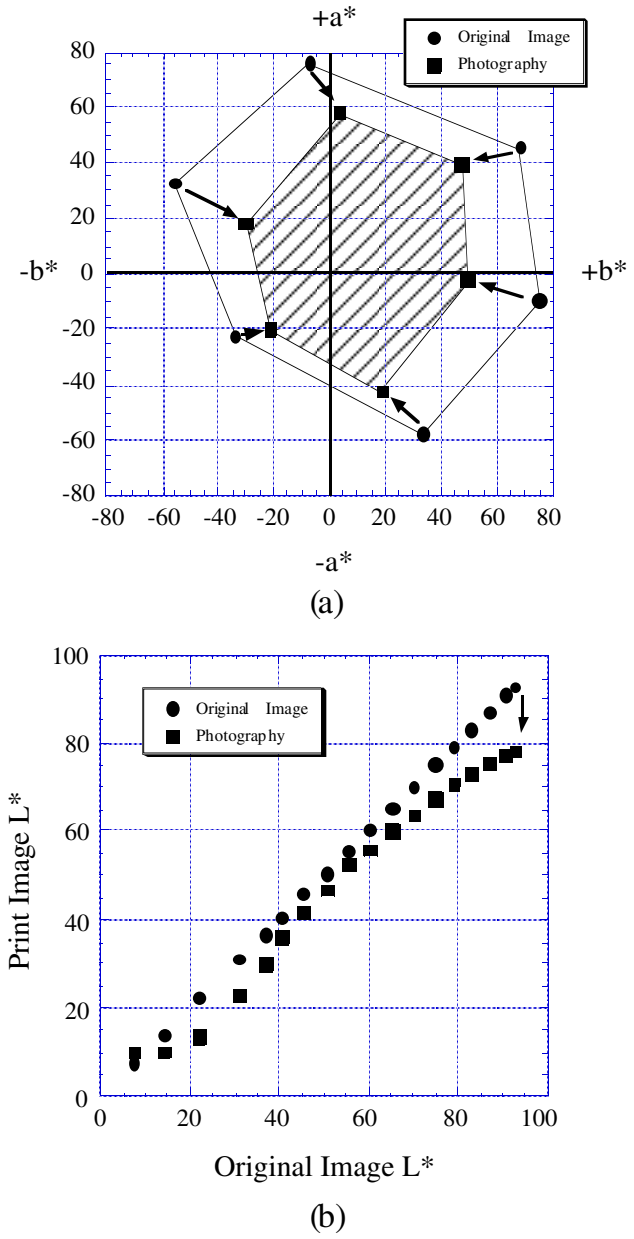

*Figure 2. Characteristics of photography, (a) Comparison between original color patch of C, M, Y, CM, CY, MY and its photo print on a*b* plane, (b) Relation of L* value between original gray scale patch and its photo print.*

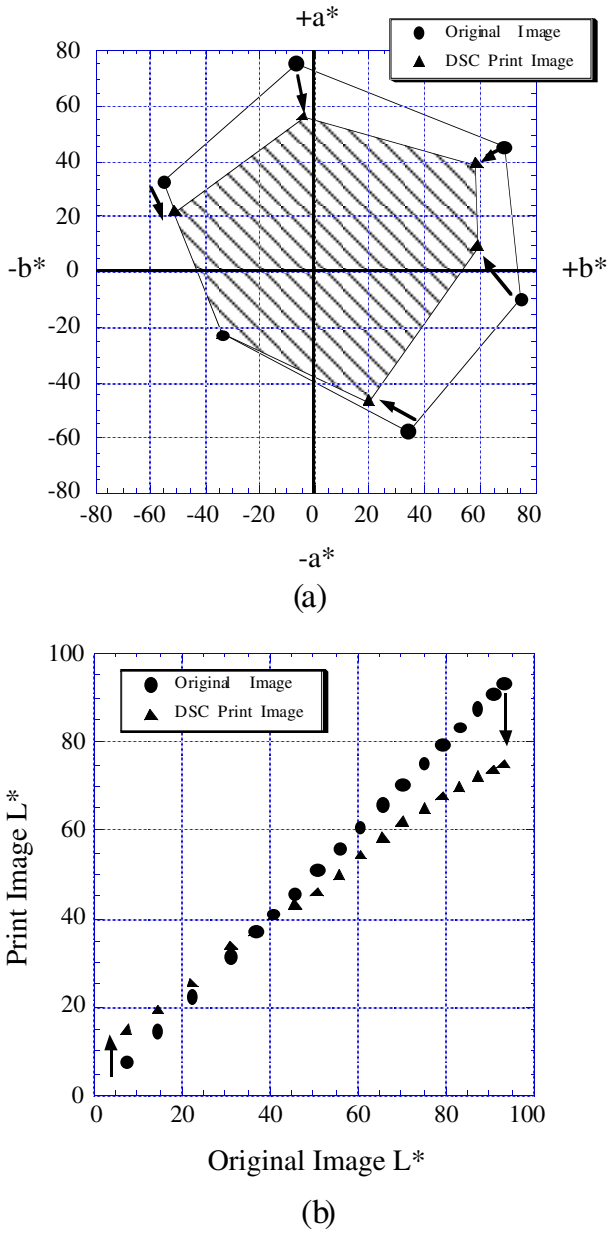

*Figure 3. Characteristics of digital still camera printing system used in this experiment, (a) Comprison between original color patch of C, M, Y, CM, CY, MY and its print by color printer on a*b* plane, (b) Relation of L* value between original gray scale patch and its print.*

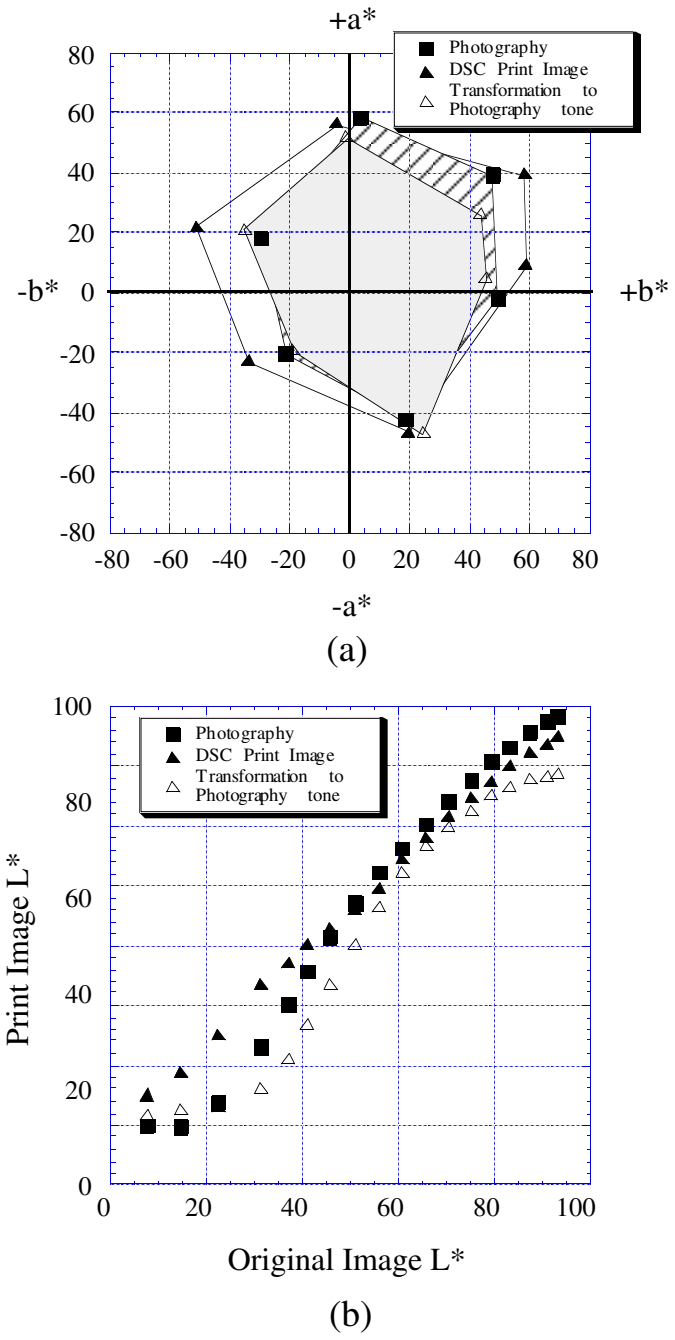

*Figure 4. Comparison between photo print and transformation to photography tone print in digital printing system. (a) Color patch of C, M, Y, CM, CY, MY on a*b* plane. (b) Relation of L* value of gray scale patch.*

Summary

With the progress of digital imaging system, various color expressions will be needed. Therefore, color image printing like conventional photo tone in digital imaging system is studied. The formulation for transformation to photo tone is proposed. The relation functions of input device and taking photo are approximated by least square fitting method and are applied to photo tone transformation.

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Biography

Watanabe Takashi is graduate course student of Nippon Institute of Technology. He gained Bs. and Ms. degrees from Nippon Institute of Technology and is now studying color reproduction technology in Hoshino laboratory of Nippon Institute of Technology. E-mail: s969022@nit.ac.jp

Kuroda Ryo is graduate course student of Nippon Institute of Technology. He gained Bs. degree from Nippon Institute of Technology and is now studying color reproduction technology in Hoshino laboratory of Nippon Institute of Technology. E-mail: s944225@stu.nit.ac.jp

Hoshino Yasushi is Professor of Nippon Institute of Technology. He gained Bs., Ms. and Dr. degrees from University of Tokyo, 1970, 1972, and 1984 respectively. After he gained Ms. degree, he joined Electrical Communication Laboratories of NTT and developed first LED printer, high speed laser printer (process speed 89 cm/s), color laser printer by using ultra elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology on 1994. He published more than 20 papers and several papers also in IS&T's Journal. He attended almost NIP congresses. E-mail: hoshino@nit.ac.jp