Direct Tonal Evaluation for the Digital Photo-Imaging System

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Abstract

In the any photo-imaging systems, the tone reproduction on the output is the one of the most essential function.

In the traditional silver halide photography, so called analog photography, the tonal characteristics of the system is evaluated by tone reproduction curve of the Camera-Through Sensitometory (CTS) technique. In the traditional system, the tonal quality of photo-image depends mainly on the medium and its developing process. Although the contribution of camera is not important factor to that quality.

In the current electronic digital photography, the tone characteristics will be evaluated by similar method to the CTS, however the image processing function of the digital steel camera (CTS) induces the remarkable effect to that quality. Thus the tonal characteristics will be affected by DSC itself. The signal career of photo image in the digital system is the image data to be more definite, detectable and electronically controllable than that in the analog system.

This paper discusses the electronic direct evaluating method for the tone reproduction of digital photo-imaging system.

Introduction

On the CTS for the traditional analog photography, the original tonal-information is introduced by camera-shooting of stepwise optical density tablet. The tone curve of developed tablet image on the medium is plotted with the relation of optical (photo) density and input photo-energy in logarithm scale. The tone reproduction is estimated by comparison of shapes and slopes of both curves for the original and reproduction.

In the current digital photography, the same principle of the CTS will be available. The distinctive feature of the digital photography is that the input image information is carried by image data divided into 256 or higher digit rate and each datum is discrete and controllable. Thus the input original and reproduction output images for the evaluation must be analyzed by more accurate factor than the optical density. The color space values for the reproduction is more exact and adaptable than the optical density.

The authors have been studying the tone reproduction of the digital photography system using magenta chart.[1-3] This paper assesses the direct evaluation of the tonal characteristics in the photo-imaging system using the 8-bits lightness step achromatic charts and colorimetric analyses of the reproduction chart images on the PC monitor and the output prints.

The authors also newly proposes the introduction of sectional classified tonal charts for the shadow, mid-range and highlight tonal regions. The detailed and clear discussion was available with such classified charts.

Analytical Procedure

In this work, the key devices were the stepwise printed charts showing the linear lightness (L*) values and the high quality digital steel cameras (DSC) for the professional use.

The charts were the home-made black and white (B/W) original form printed by pigment ink type B/W ink jet printer, Epson PM 9000PX.

Figure 1 shows the pattern and reproduction of the 8 bits linear lightness B/W step chart. The basic chart pattern was the same concept as that reported in the former paper.[4] The arrangement of the chart pattern was as follows; 1) to divide a print into 16 sections and to assign 16 groups of serial printing data level individually, 2) to divide each section into two parts, the left side part printed by constant (16X)th level datum and the rest of right side part was vertically divided into 16{16(X-1)}th to 16{16(X-1)+16}th level data.

In this paper, the calibration was done to check the lightness values in every 16 sections. Moreover the traditional linear density step gray scale chart was used as the reference.

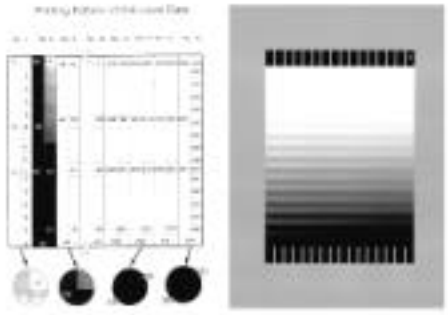

Figure 1. The pattern of 8 bits linear step chart and its reproduction

Figure 2 shows the lightness and density characteristics of chart. Both values were measured by direct colorimetric and densitometric analyses on the printed original chart using the contact type color meter, Macbeth Spectrolino. The lightness change was linear with the input data level for the printing.

The dynamic range of L* value was 75 from L*=85 to L*=10. It was twice as that of the former magenta chart.[2] The density range in the neutral density of it was over D=2.2.

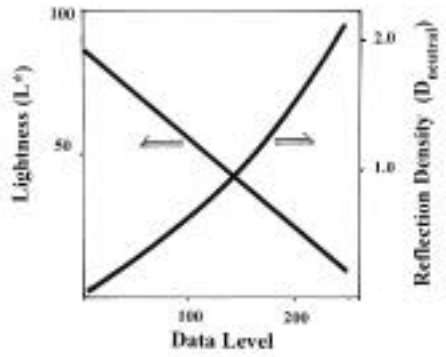

Figure 2. Lightness and density characteristics of Chart.

Figure 3 illustrates the procedure for the analysis. In the input stage, the chart was illuminated by D_{50} fluorescent lamp. The cameras were four high-end DSCs. Fuji FinePix S2 Pro, Canon D60, Nikon D100 and Sony DKC ST5, having the high density CCD or CMOS imagers.

Before shooting the target, the white balance calibration was done to take the illuminated white paper follow to the individual DSC's manual. The exposure rate were mainly controlled by iris of DCS's lens to get the specific L* value of 85 for the white base paper corresponding to be the Data Level of 0. This procedure followed to the "Softcopy Evaluation" method described later on.

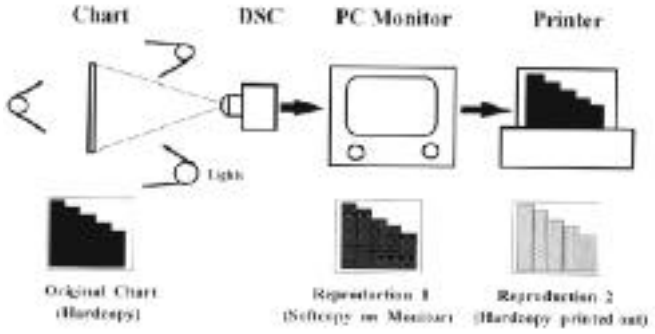

Figure 3. Analytical procedure.

The condition of the output image data from the individual DSC was the RAW data formatted by each camera system and their color space were calibrated by s-RGB or NTSC color space systems.

After shooting the target, the image data of chart were first displayed on the computer, PC monitor under the plug-in Photoshop graphic software and then checked the colorimetric values of CIE/LAB • L*a*b* (1976) for individual sections on the displayed reproduction of the chart image. The data converting operation using the plug-in software proceeded from RGB to XYZ and finally to L*a*b*. This is the on-line procedure named as the "Softcopy Evaluation".

The relation of lightness, L* colorimetric value and the input image data level suggested the tone characteristics of individual DSC. The qualitative discussion will be available to compare the slope of curves for various DSC.

Then the image data was supplied to the above mentioned B/W digital printer and the reproduction hardcopy on the photo-paper level receiver was formed as the same style print as the original chart. On the reproduction, the colorimetric values of the same CIE/LAB values measured by above mentioned contact color meter. This procedure was named as the "Hardcopy Evaluation". The tonal evaluation was done as the case of the "Softcopy Evaluation" This is basically the same style evaluation as the current photography systems.

On the discussion, the three dimensional real photography images were introduced. These were shot by above mentioned DSCs and printed to hardcopy reproduction for the reference. This kind of reproductions were printed by thermal dye transfer digital color printer, Sony UPD 70.

Result and Discussion

The discussion proceed to examine the relation of lightness values and data level on the original and reproduced chart images displayed on the PC monitor and printed on the output hardcopies.

On the "Softcopy Evaluation", the L* values of the 16 sections obtained by operation on the reproduction chart images displayed on the PC monitor were linear with the data level. On the "Hardcopy Evaluation", the L* values on the 16 sections obtained by direct colorimetry on the printed reproduction chart image were also linear with the data level. Evaluation" and "Hardcopy Evaluation".

Figure 4 shows the results of "Softcopy Evaluation" and "Hardcopy Evaluation" In the graph of the "Softcopy Evaluation, the L* characteristic curves for the four DSCs shows linear with data level, although they have different slopes. In those of the graph for "Hardcopy Evaluation", the L* characteristic curves also shows the same conditions. The slopes for the "Softcopy Evaluation" show generally steeper than another.

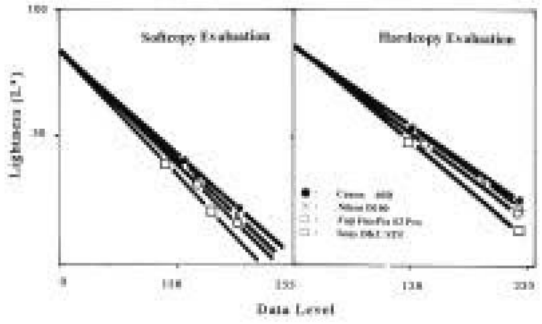

Figure 4. Characteristic Curves for Softcopy and Hardcopy Evaluations

Figure 5. Reproductions shot by DSCs in photo-studio and printed by the same printer as to produce charts.

Figure 5 shows the reproductions of plaster bust image shot by the same DSCs as above mentioned. The production process was as follows; shooting the plaster bust object in the photo-studio under the electronic lights illumination. The illumination ratio of two electronic lights was 3 : 1 for right and left side. The exposure condition of individual DSC is to fix the L* value of 85 on the forehead part of bust using the "Softcopy Evaluation" technique. The reproductions were printed by thermal dye transfer printer. It is one of the most excellent digital printer showing the perfect tone reproduction.

On the reproductions, the tone change of highlight to shadow in their foreheads are affected by individual DSC. The reproductions showing the gentle tonal change were obtained by shooting of the same DSCs represented the gentle slopes in the both L* characteristics in Fig. 4. The reproductions showing the radical tone changes were shot by DSC represented steep slope in L* characteristics.

These results on the Fig. 4 and 5 suggest that the L* characteristics for the displayed and printed reproduction single color chart images reflected to those of tonal characteristics.

In the traditional photography, the tonal characteristics were discussed by shape and slope of tone reproduction curve expressed by the relation of density of reproduced chart image and the input photo-energy in the logarithmic scale.

Figure 6 shows the traditional tone reproduction curves for the reproduced chart images printed on the above mentioned inkjet prints. This density characteristic curves corresponded to the results of the conventional CTS.

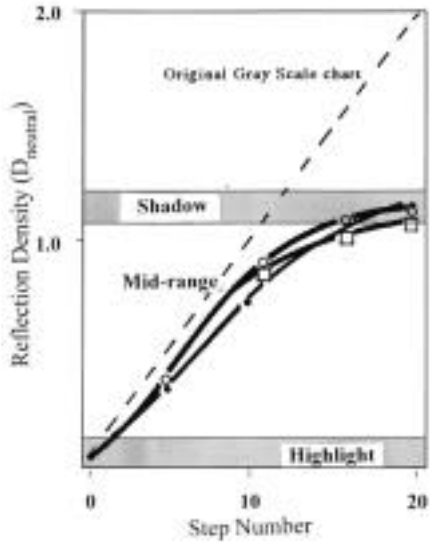

Figure 6. Traditional HD characteristics of hardcopy prints shot the gray scale by DSC and printed on the B/W inkjet prints.

The curves show similar S shape as the case of the current photography. In that photography, the tone reproduction curve presented by density characteristics was divided into three sections in convenience. According to the International Standard Organization document,[5] there were three sections on the density characteristic curve for the tone reproduction. These were named as follows; the top saturated high density part is to be the shadow, that of bottom saturated low density part is to be the highlight and the mediate linear part represents to be the mid-range. In Fig 6, the density range of shadow corresponds to density over 1.2, that of highlight are densities under 0.2.

The results shown in Fig. 2 and Fig. 6, the shadow section corresponds to be the L* value range of under 25. Those of the mid-range and. highlight are L*value ranges of 87 to 25 and 91 to 87, respectively.

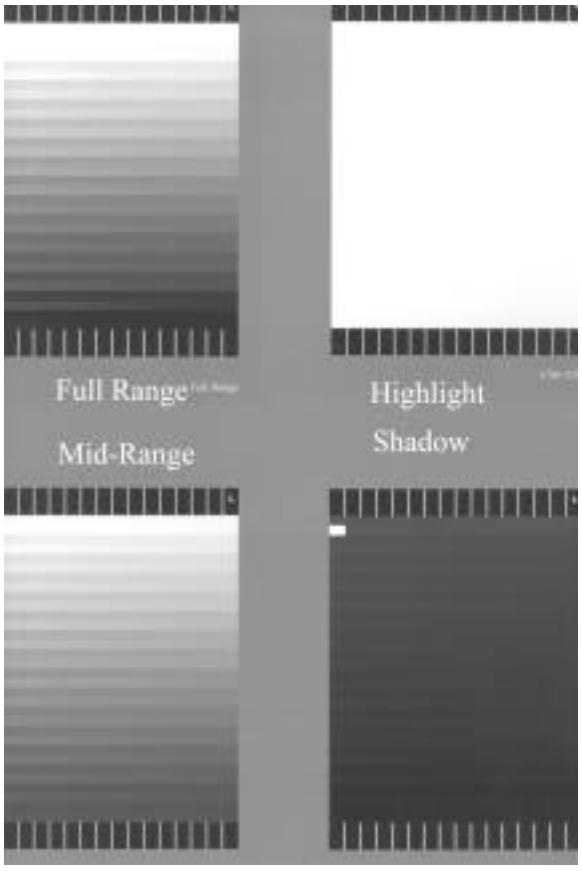

Figure 7. The reproductions of three sectional L linear step charts.*

The special designed L* sectional linear step charte were formed for the detailed tonal discussion.

Figure 7 shows the reproductions of standard full range chart and three sectional charts.

Figure 8 shows the L* condition of sectional charts having L* ranges shown in Fig. 7. These charts showed all linear step L* characteristics.

Figure 9 shows the result of the "Softcopy Evaluation". The effects of DSC appear on a larger scale and more distinctive than the results shown in other figures.

A more interesting thing is that the order of slopes for three DSCs changed in the sectional L* characteristics.

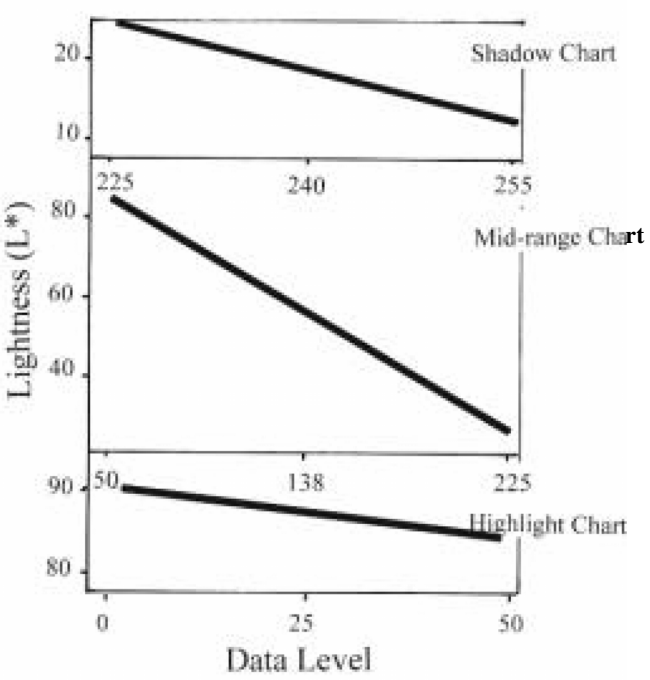

Figure 8. L conditions in the three sectional tonal charts.*

In the case of DSC of Sony DKC ST5, the slopes of L* characteristics curves are very steep in the highlight and mid-range sectional charts, however it was the lowest and near flat in the shadow chart region.

In the cases of DSCs of Fuji Finepix S2 Pro and Canon D60, the slope of formers in the highlight region is steeper than another. Although in the midrange chart region, the order replaced and the latter shows the steeper slope.

Conclusion

The L* linear step chart is very useful to the discussion of tonal evaluation for the electronic digital photography.

The principal analysis is to check the relation of L* condition of image and image data level for the "Softcopy Evaluation". The second is the total analysis to check that of reproduction print showed the equal trend for the "Hardcopy Evaluation".

Of course in the current proposal, the L* analysis in both evaluation processes depends on the different measuring manners and thus the proper comparison is difficult between both evaluation. Although according to this proposal, the qualitative direct evaluations for the device and system are available to shoot charts by DSC, to display reproduction on the PC monitor with the operation using the graphic software and digital printer.

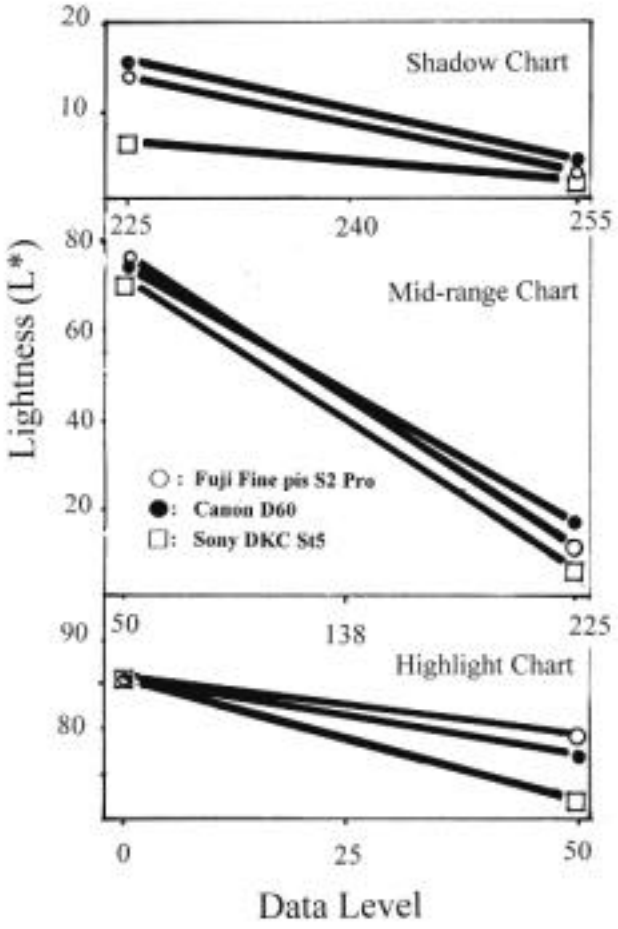

Figure 9. Results of "Softcopy Evaluation" usin the tonally sectionalized chart

The introduction of tonal section chart is the first proposal. It will be useful for the discussion of detailed tonal characteristics and the comparison of tonal capabilities of the traditional and the novel digital photography systems.

More study is required to blush up and to establish the quantitative evaluation. The authors appreciate to Mr. Yoshiyuki Ozawa of Seiko Epson Co. and Ms. Toyoko Fujii of Sony Corp. for their suggestions and supports of printers.

Reference

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Biography

Shin Ohno had received his BS and Doctor of Engineering degrees from Chiba University and Tokyo Institute of Technology, Japan, in 1962 and 1979, respectively. He entered the Technical Research Laboratories of Japan Broadcasting Corporation (NHK) in 1962 as a research associate. He had worked in the field of media and systems for the recording of TV programs. In 1989, he entered the Electronic Photography Division of Sony Corporation as the chief engineer. He worked on the development of electronic and digital still cameras and digital photo-printers. In 1998 he was appointed as a guest professor of the Graduate School in Chiba University. He retired from Sony in 1999 and joined the School of Photography, Tokyo Institite of Polytechnichs as a professor in 2000. He was the director of IS&T's Tokyo Chapter from 1988 to 1996 and a VP, the board member of that society from 1996 to 2000. Now he is the President of ISJ and IS&T Tokyo Chapter. He was the steering chair of ICIS '02 Tokyo Conference. He has also chaired many conferences in IS&T and the other imaging societies.