

Image Quality of Digital Photography Prints: 1

Color Expression Quality of Thermal Dye Transfer Prints

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Abstract

In digital hardcopy systems, color images are printed by digital data supplied to the printer. The number of digital levels of information is decided by conditions of image processing an d manipulation using a personal cornputer. For each color, the typical number of levels for continuous tone renditions of primary color images of red (R), green (G) and blue (B) is 256 levels, equivalent to be 8 bits (2^8 steps).

This paper discusses the relation of number of levels of image data and the color reproduction on thermal dye transfer prints. Further, it discusses the appropriateness of the thermal dye transfer printing for continuous tone pictorial image formation. The evaluations of sample picture printed by digital data used both subjective human viewing and objective calorimetric measurements to discriminate between different patches printed by step wise 256 level data. The results show that around 60 to 85 % of input 256 level image data respond to express achromatic and chromatic densities and around 10 million-colors were estimated to be independently recognizable on the print.

Introduction

In the current digital imaging systems, the information of the original is carried by digital image data and manipulated by digital image processing method using personal computers. In the usual imaging system, the color information is carried by additive primary color signals of R, G and B from the captured object images by camera or scanner, or created images using computer is carried by additive primary color signals of R, G and B. Those signals in the digital imaging system are assigned as data. The input color image date of R, G and B supplied to the printer are converted to color hardcopy images on a medium expressed by subtractive primary color materials of cyan (C), magenta (M) and yellow (Y). Thus all color images on the prints are formed by simple and mixed consists of C, M and Y colorants.

The color rendition of hardcopy image is directly related to the tone reproductions of C, M and Y images on the print. On a print expressed its tone reproduction using the direct density method, the color reproduction is realized by quantitative depositions of C, M and Y colorants on a substrate. The thermal dye transfer printing is one of the best hardcopy systems because the dyes are directly transferred from donor to print. Thus this print is a nice example to examine the response of the input information to the output printed image.

These examinations were done using sample prints having a special pattern printed by 256 levels of input image data. The samples were made by so called sublimation dye transfer prints. The main point of the examination was the discrimination between individual density steps printed by serial image data. The evaluations included both subjective human viewing to measure just noticeable differences and objective colorimetric measurements to get the quantitative change of physical values .

Experiments

The test pattern on a sample print is shown in the previous paper.[1.] The consist of the pattern was as follows:

1) To divide a print into 16 sections and to assign 16 groups of serial printing data levels individually. These sections numbered to No. 1 to No. 16 and the first No. 1 section was printed by step wise 1st to 16th level image data and the last No. 16 section was assigned for printing of 241st to 256th level image data.

2) To divide each section into two parts, the left side was printed by constant (16X)th level datum and the rest of right side was vertically divided into 16 patches and printed by 16[16(X-1) + 1]th to 16th ([16(X-1) + 16]) level data. X was integral number of 1 to 16. As the result in the each section, the angle shape consolidated patches printed by constant [16X] level data surrounded 15 patches printed by step wise [16(X-1)+1]th to [16(X-1) + 15]th level data.

3) Print sample size was 128 mm square and the area of each printed patch was 4 x 8 mm^2.

The samples were printed in four colors of C, M and Y and Blk. on the white receiving paper. The C, M and Y primary color samples were made by single transfer of dye from ink ribbon and the Blk sample was made by multiple transfers of C, M and Y dyes. The printer was the A4 size sublimation dye transfer printer, Sony-UPD 8800 and the printing materials of dye ink ribbon and receiving paper were the genuine media for it. The receiving paper was the non-transparent opaque plastic film and contained brightening agent on the surface layer of receiving side.

When printing of samples, the electrical power supplied to the printing heater head was linearly divided into 256 levels. Thus the highest 256th level date supplied the highest power making the maximum print density. The lowest 1st level was that of 0 electricity showing no density change. The density difference between each step were not constant. The gamma control of the head drive was off. These color samples were printed by 256th, level data respectively.

We evaluated the print samples using colorimetric measurements for a physical measure and color differences between adjacent patches using for human viewing measure. The subjective viewing examination was carried out using the following conditions: the sample prints were viewed in a light box (Macbeth Spectral Light SPL 75B) under the normalized illumination of 7,500 K, 1,200 lx, the viewing distance was the distinct vision of 400 mm and the viewing angle was about one degree. The colorimetric measurements were mainly to examine the differences of color density and chromatic physical values between the adjacent [16X]th and [16(X-1) + 15]th patches in every 16 sections.

Results and Discussion

Subjective Evaluation — Visual Examination of Density Change

The visual examination was carried out to watch the sample prints setting in the light box.[2] On the viewing of the sample prints, the check points to recognize the density change were the boundaries of adjacent patches. The typical boundaries were the [16(X-1)+15]th and [16X]th levels in every 16 sections. On the examination, if the observer saw boundaries between adjacent sections, then these patches were discriminative. Also if all 16 patches showed different colorimetric densities in those sections were considered to be discriminative.

The results are the average of two observers. In the cases of Blk and M color samples, the boundaries between ten patches in the first No. 1 section (printed by 7th to 16th level digital data) could be identified and the boundaries of the first six patches showing the lowest density region could not be discriminated from each other. In the No. 2 to No. 15 sections, all 15 boundaries of full 16 patches were discriminative from the adjacent patches . In the last No. 16 section, the boundaries of patches showing high density printed by 244th to 256th and 251st to 256th level data could not be recognized on M and Blk samples, respectively. In other words, observers could not discriminate between the first 10 and the last 5 patches in the Blk image, leaving 241 discriminative patches. Observers could not discriminated between the first 10 and the last 12 patches in the M image leaving 234 discriminative patches. The sum of recognizable patches in the every sections corresponded to the total number of discriminative density levels. In the case of the achromatic color sample of Blk, over 240 of 256 level digital data were considered to make the visually discriminative density levels. In those of the chromatic color samples, 234, 227 and 211 appearance levels were thought to be recognizable for M, C and Y samples, respectively.

The number of discriminative color appearances on the full color print is estimated to be a product of C, M and Y appearance levels. Thus in this thermal dye transfer prints, the number of visually recognizable color is considered to be 11,207,898 ($234 \times 227 \times 211$).

Objective Evaluation — Densitometric and Colorimetric Measurements

There are two categories of objective physical examinations to check the color; one is the color density and another is the color space values.

On the micro-densitometric traces of individual sections, the distinct step wise density changes could not be measured, even in the high numbered dark sections of the sample. Of course in the low numbered light regions, the traces of density change showed very gentle slopes. The boundaries of patches printed by serial level data could not be recognized by density measurements.

The second colorimetric method was the examinations using color space values of L*, a* and b* (CIE 1976) for each patches on the above color samples measured by spectrometer. At first, the color space values of typical patches were measured on the four color samples.

The relation of lightness values, L* of sample and the input data level. The result of Blk sample, the combination of M, C, Y images, show large change of L*. The Y sample shows small change and L*.

The mapping trace of Y indicates large b* value changes, however small a* value changes. That of C shows about equal changes both a* and b* values. The trace of M shows large a* value changes and small b * value changes. This evaluation using a* and b* values are good but not perfect to examine the color changes on the three color samples.

The final evaluation was the introduction of the color difference, dE obtained by operation of three color space values of L*, a* and b* on the adjacent patches as the following equation:

$$dE = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2} \qquad (1)$$

In the equation (1), ΔL^*, Δa^* and Δb^* are differences of L*, a* and b* values between those of patches printed by [16(X-1) + 15]th and [16X]th level data as the case of subjective examination. The result was shown as the relation of color difference value, dE and the data level. In the identification of color difference, dE = 1 is thought to be the critical point to recognize two colors in dependently.[3,4]

In the higher numbered sections showing dark colors, dE values for three colors of C, M and Y images fall the critical point at patches printed by data level of the 208th region and that of Blk exceed at the level of 240th.

The color difference values of dE between the adjacent patches were useful to check the color change. In this experiment, we found 140 levels for C print, 180 levels for M print and 156 levels for Y print. The color number estimated by color difference value, dE exceeding 1.0 was 3,931,200 ($140 \times 180 \times 156$).

Conclusion

The color expression ability of the thermal dye transfer print was estimated by objective and subjective examinations. The result of objective evaluation, the number of recognizable color responding to the input of 2^8 step R, G and B digital data was considered to be 11,207,898. It is equal to 67% of possible number of 16,777,216, equivalent to 224. On the other hand, the result of dE.Lab color metrics, the color differences indicated the number of 3,931,200. In the case of the R, G and B color image data levels of 7 bits (2^7 steps), the maximum number of color expression is counted to be 2,097,152.

The results of this work suggested two major advantages of thermal dye transfer print to reproduce the continuous tone pictorial color hardcopy. The first advantage is that the reproduction range of density and color expression matches the range of the quantization of input image data levels. At present, the most useful and familiar quantization image data level is supposed to be 8 bits. On the thermal dye transfer prints, the characterized tone rendition will be expressed in the achromatic image. It was the integration of the renditions made by three colors. In the black and white sample print, 240 of 256 levels input image data responded to the recognizable print densities. It was estimated by most sensitive subjective evaluation to check the boundary of adjacency patches showing minimum density difference. Furthermore, the result of objective evaluation to check the color difference, in the middle data level range excluding the black and white compression regions, finer pitch level image data were supposed to be able to express recognizable tone change. It was shown that the use of image data range of 10^8 is almost sufficient. The presentation of around four to twelve million colors on the print are available from 256 levels of R, G and B image data supplied to the printer.

The second advantage is the adaptability of thermal dye transfer printing. It shows continuous tone and plenty color reproduction. The ability to print patches that appear uniform and different from patches whose digital level is only 1 digit difference is the evidence of low noise and high uniformity. The noise and uniformity performance is better than the above fine reproducing identification will be specifications for continuous tone reproduction pictorial images.

In summary the thermal dye transfer printing method is an outstanding media to reproduce continuous tone reproduction on the pictorial hardcopy.

References

1. Shin Ohno, "Digital photography and color printing", *JISTJ*, **40**(6) 556 (1996).
2. Shin Ohno, "Consolidated evaluation of chained imaging equipment in multi-media environment", *J. SPSTJ*, **59**(1) 155 (1996).
3. Motoro Kawakami, "Color Science Handbook" p.257 (1989) Univ. of Tokyo Publishing.
4. Hitoshi Komatsubara, "Evaluation and improvement of color image" p. 21 (1992) Japan Engineering and Technology Center.