Image Classification and Optimized Image Reproduction

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Abstract

Optimized image reproduction is becoming more critical as parallel publication is gaining field. The print buyers' and end users' demands for quality are also increasing. By using a common format (ICC) for characterization of color units it is easier to determine the color gamut of a device and thereby optimize a printout. The characterization of a color unit is achieved by printing and measuring target values in a color chart. There are a number of different color charts on the market, all with one thing in common; they are assumed to be valid for all types of images, no matter if the relevant image information is located in hi-key areas, low-key areas or in the mid-tones. The effect of this is that too few color tones containing key image information can be analyzed.

To correct for this, new adapted color charts have been created based on technical and visual image category analyses. A number of tests have been carried out using extreme images with their key information strictly in dark and light areas. Preliminary results show that the image categorization using the adapted color charts improves the analysis of relevant image information with regard to both the image gradation and the detail reproduction. The new adapted color charts preserve details in the low-key areas, producing a more distinct image with a better agreement with the original. Evaluations have been made using a test panel and the pair-by-pair comparison method.

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Images with the key information in hi-key areas were also test printed using the adapted color charts. The results here show no significant enhancement in image quality. However, images with the core information in the mid-tone regions show an improvement in reproduction compared to the original. The tests show that an improved image reproduction can be obtained by adapting the ICC profiles used to the specific image types to be printed.

Preface

The graphic arts industry is still struggling with a way of producing good reproduction of original images. One major progress is the common ISO standard of determining a color unit gamut, called ICC profile. This makes color communication easier, but there are several factors that can jeopardize the result: several color management software developers, different color charts and color calculations for characterization of different output units. There is a specific standard (ISO 12642) for the characterization of output units, but vendors often produce their own charts for the characterization of color units. There are quite a few color management vendors on the market with their own ICC-profiling software: Agfa with Colortune, Gretag Macbeth with Profilemaker Pro, Heidelberg with Printopen, to mention a few. All color charts used for characterization today work in a general way and do not consider the type of image category being reproduced.

Images can be categorized into different groups depending on the image content, key information and tone distribution. Some of the image categories mentioned in some literature today are: hi-key , normal key, low-key (Field Gary G.,1990), gray balance and tertiary color images.

Hi-key images

“Snow images” (Germundsson, Olsson, 1990). Images in this category hold their main information in the high-key areas (lighter tones). This category is sensitive to burning-out problems when the white point is set incorrectly in a reproduction. However hi-key images rarely cause any printing problems, because of minor dot gain in the lighter tone areas.

Normal-key images

"Mid-tone images" (Germundsson, Olsson, 1990). This category has tone distribution throughout the tone scale with the main information in the mid-tone section. This category is easy to reproduce since it holds information in a wider tone range. However, the mid-tones causes a large dot gain which needs to be compensated for.

Low-key images

"Night images" (Germundsson, Olsson, 1990). The main information is found in the darker image tones. Our eye has difficulties to distinguish between tone changes in the darker region because of high ink coverage. There is also a risk for filling-in problems when printing a low-key image.

Gray balance images

"Gray balance images" (Tidningsutgivarna, Färgpressen 1991). This category holds its information near neutral black. Conventionally a black and white image would be reproduced in the colors cyan, magenta and yellow (chromatic reproduction). A three color reproduction, without black, is more sensitive to color shifts in a print run. A certain amount of black is usually added to stabilize the variations in the print run, which is a degree of achromatic reproduction or gray component replacement.

Tertiary color images

"Dirt images" (Tidningsutgivarna, Färgpressen 1991). A category where the three primaries (C, M, Y) are dominant causing a tertiar color usually in the darker tone scale. The tones are close ly distributed which makes it challenging to reproduce the tones correctly in order to avoid a flat reproduction. The difficulties are due mainly to dot gain and relatively high ink coverage.

Objective

One purpose of this work is to use the knowledge of the categorization of images to improve the quality of color reproduction, and this is achieved by adapting standard color charts. Another purpose is to evaluate different image categories with the purpose to see if an advantage can be taken of the output characterization which is aimed at a specific tone distribution, as compared to static characterization, which is aimed towards any kind of tone distribution.

Limitations

This work is concentrated on the study of how low-key images are affected by the specific characterization. Low-key images are more troublesome to reproduce correctly. The key information is concentrated in darker tone regions where small changes in reproduction give large variations in print. Only a few minor tests have been done concerning normal-key images and hi-key images.

Method

Test charts commonly used today for output characterization were studied to evaluate how the tone steps are distributed for output characterization.

From this study a new set of color values were used for creating an image adapted test chart, that was changed with respect to the gamma and gradation values normally used. The category adapted test charts were printed in a controlled environment. Spectral measurements of the new test charts were taken. New output profiles were calculated and applied in the RGB-to-CMYK conversion for the specific image category it was aimed for. A validation print was made with the new separation values applied to the specific image category it was aimed for. The evaluation of the result was made by the subjective method, pair-to-pair comparison. 50 persons with a graphic arts background judged the result. An objective evaluation was made by taking instrument readings of luminance values.

Specifications of the software used for the creation of the test chart in the study:

Software:	Adobe Illustrator 9.0, Adobe Photoshop 6.0.1, Gretag Macbeth Profilemaker 3.1.4, QuarkXPress 4.0.3
Hardware:	Macintosh PowerBook G3
Measurement:	Gretag Macbeth Spectroscan

Performance
The stages of the test:

1) The new image adapted test charts were produced
2) The new test charts were printed
3) Spectral readings of the new test charts were taken
4) Profile creation of the new test charts based on the measured test charts were made
5) RGB-to-CMYK separations of hi-key and low-key images with the new ICC profiles were performed
6) Validation print of the new separations was carried out
7) Subjective and objective validations of the new validation print were performed

1) Production of the new image adapted test charts

A study of some commonly used CMYK test charts was made. The reference values for the gradation of the test chart were specially considered. A further study was made of different hi-key and low-key images tone distribution. By treating the test images with a mosaic filter to reduce the number of image points, Lab-values of the image were taken and brought into a color gamut of the image, see figure 1.

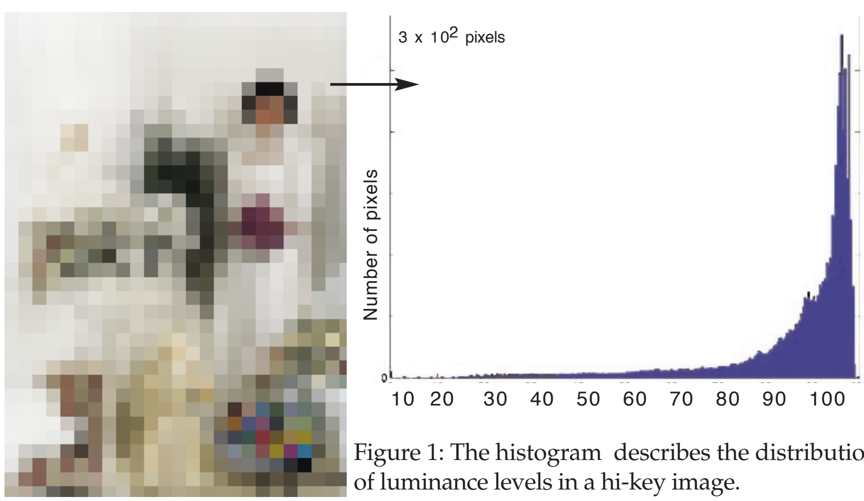

Figure 1: The histogram describes the distribution of luminance levels in a hi-key image.

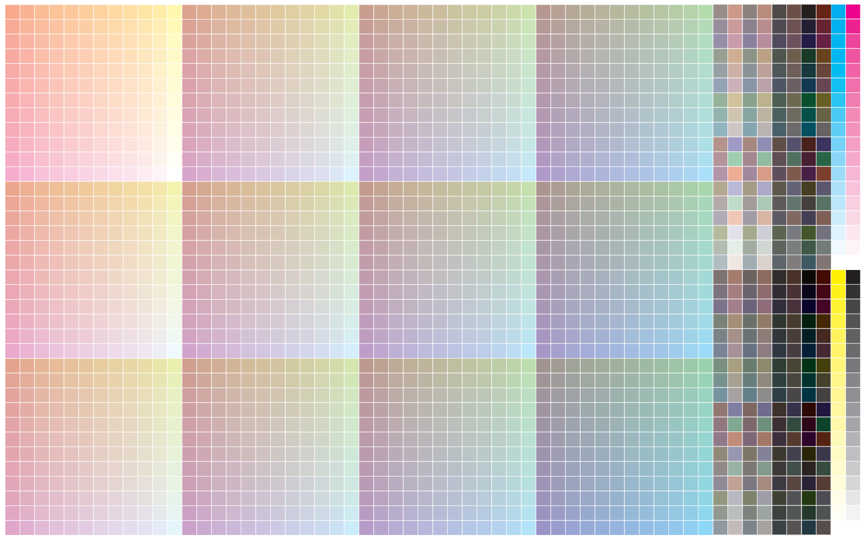

Figure 2: An example of an image adapted test chart for low-key images, made in Adobe Illustrator.

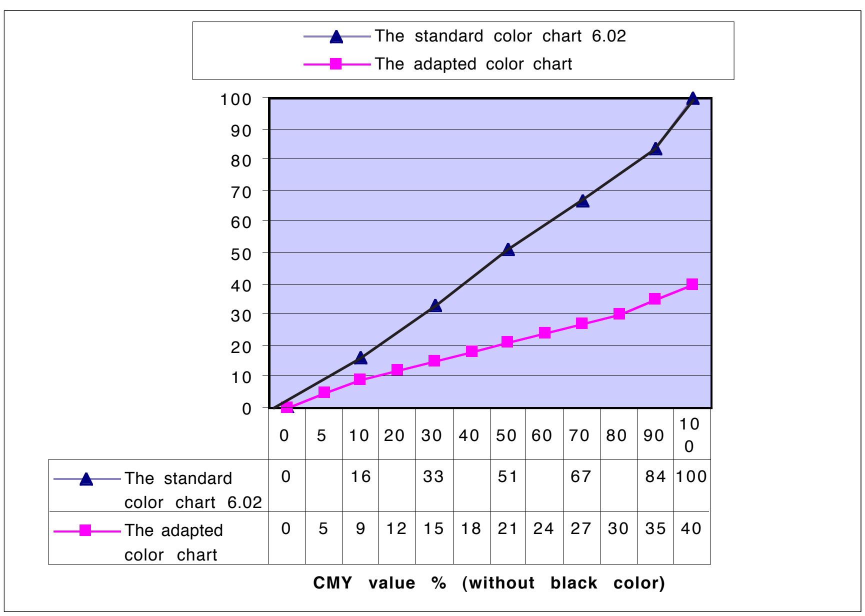

Figure 3: A comparison of CMY-value distribution between test chart 6.02 (GretagMacbeth, Profilemaker 3.1.4) and the adapted test chart for low-key images.

The color gamuts of different extreme image categories were compared objectively by luminance numbers and brought into two base groups: hi-key and low-key. The result showed that for the hi-key category the major image information was found in the luminance range of 60–100 which is a CMY-value of 0–40%. A similar study for the low-key image category had a luminance range of 0–40, which gave a CMY-value of 60–100%. These CMY-values were used for the creation of parts of the test chart. They were also the base for the gradation build-up. New test charts were created for the hi-key and low-key image categories by studying the gradation curves for the categories, see figure 2.

The test chart 6.02 from Gretag Macbeth was compared to the adapted test chart prioritizing images with its main tone distribution in the low-key area. The image adapted tone curve presents the darker image information better by achieving a larger tone spread in this area, see figure 3.

Another way to create the image adapted test chart is by using a standard test chart (Gretag Macbeth test chart 6.02, see figure 4), and adapting the gradation curve in Adobe Photoshop, see figure 5. Typical gradation curves used for optimizing the tone distribution for a hi-key and a low-key image were used, see figure 6. New reference data were produced for each test chart.

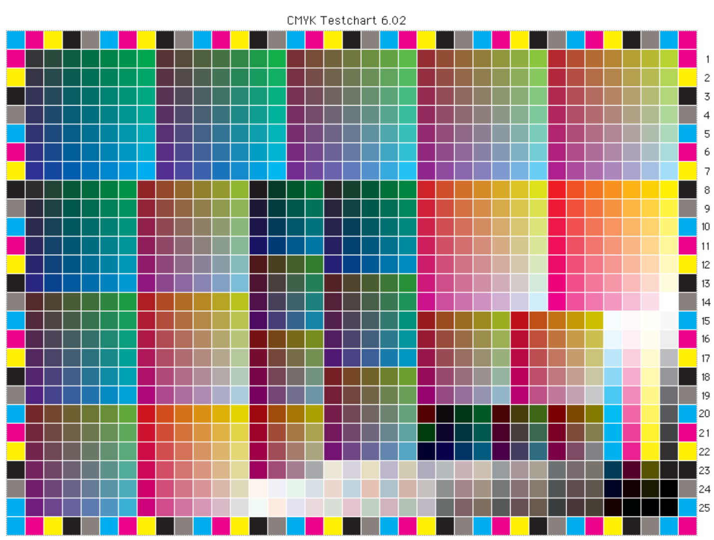

Figure 4: Test chart 6.02 (Gretag Macbeth, Profilemaker 3.1.4).

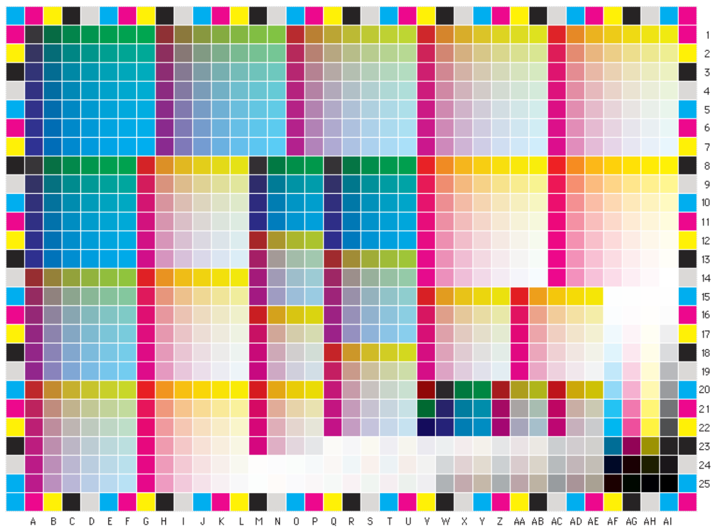

Figure 5: An image adapted test chart built from test chart 6.02 and aimed at low-key images.

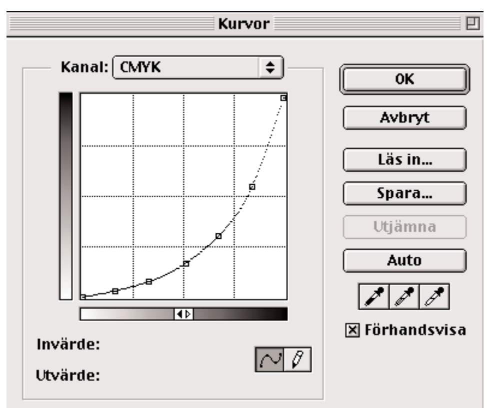

Figure 6: The "Curves" setting in Adobe Photoshop, applied to the standard test chart 6.02, to produce the adapted test chart for low-key images.

A total of ten different test charts were created, aimed at hi-key and low-key images respectively.

2) printing the new test charts

a) Pre-press preparation
The new test charts were positioned in a layout program aimed for the tests. The test charts were mounted in QuarkXPress 4.0.3. Negative-films (Fuji Neg.) were printed on a Fuji Celix 4000, and copied to Fuji Negative plates.

b) Press configuration, offset printing
The test charts were printed in a 5-color sheetfed press used exclusively for testprints. Optimum print density was established and 100 sheets were taken.

Specifications for the press run:

Offset press:	Heidelberg SM 74-6
Ink type:	Akzo-Nobel Lito Flora NT
Paper:	MultiArt Gloss 130g/m^2 150g/m^2
Color order:	KCMY
Fountain solution:	Aqualith Z, 2%
Alcohol :	IPA
Blankett:	QL Blue Saturn
Press speed:	9000 sheet/h
Impression:	0,18 mm
Pressroom conditions:	20°Celsius, 50% humidity.

3) Spectral readings of the new test charts

A spectral measurement of the test charts was performed with the spectrophotometer, Gretag Macbeth Spectroscan. Five sheets were chosen randomly and measured. A weighted average value was calculated in order to take into account the variations in the print run.

4) Profile creation of the new test charts based on the measured data

The output CMYK-profiles were calculated by Gretag Macbeth profiling application, ProfileMaker 3.1.4. 16-bit profiles were created. All profiles created used the same CMYK-separation settings.

Separation settings for the ICC profiling:

Black start	0%
Maximum black ink	95%

Total ink coverage 320%
UCR (Under Color Removal) for the hi-key images
GCR level 2 (Gray Component Replacement, level1-4)

5) RGB-to-CMYK separation of hi-key and low-key images with the image adapted ICC profiles

All test images were saved in Adobe-RGB format and separated with a perceptual rendering intent using Heidelbergs CMM (Color Matching Method) as a color engine for color gamut conversion.

6) Validation print of the image adapted profiles

Hi-key, normal-key and low-key images were test printed under the same conditions as the first press run. The density levels were controlled throughout the press run to ensure an even inking.

7) Objective and subjective validations

The objective evaluation was performed by measuring the printed luminance values (L) of grayscale strips, see figure 7. The strips were produced in the Lab color mode and separated with the image adapted and the standard (6.02) ICC profiles in the same way as with the images. The grayscale strips run from L=100 (white) to L=0 (black) in steps of L2. The luminance value (L) was measured from five strips and the weighted averaging function was used to acount for density shifts in the print run. The aim was to see if this objective study supported the result achieved from the subjective study.

Pair-to-pair comparison was used as the subjective evaluation method. 50 observers (from the graphic industry and students of Graphic Arts Technology, University of Dalarna) were used for the evaluation process. The evaluation was established under controlled conditions using a viewing booth with a color temperature of 5000 Kelvin and a Ra-index greater than 90. Three types of evaluations were made: gradation, original matching, and a comparison between a standard test chart (6.02) and the image adapted test chart.

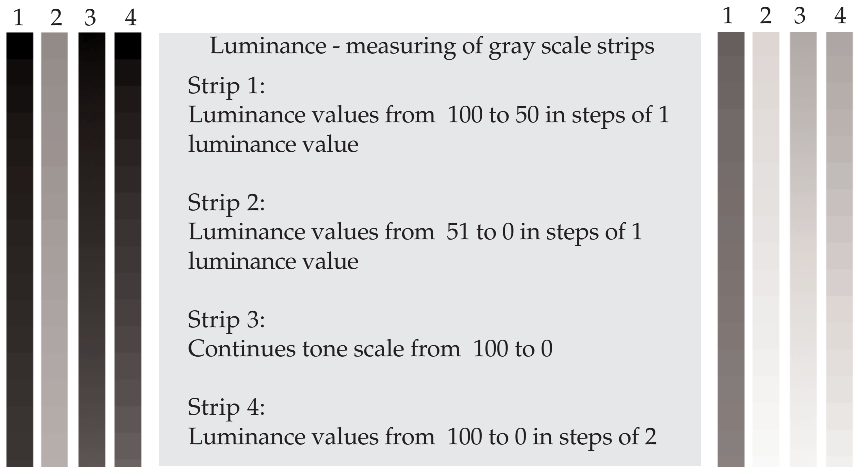

Figure 7 : Objective evaluation of grayscale strips produced with the 6.02 ICC profile and with the low-key image adapted profile.

Results

The subjective evaluation showed that low-key images separated with image adapted test targets, gave a better result concerning gradation and shadow details, see figure 8. All of the tested image adapted test charts gave a comparable result or noticeable improvement compared to using a standard test chart for output characterization. The result also holds when comparing the reproductions to the originals. The result with the hi-key images showed no significant differences compared to the standard test charts. A further test was performed using a normal-key image. It gave similar results as with the low-key image.

The objective evaluation, using grayscale strips, supports the results of the subjective method. The grayscale strips' luminance values were measured with a spectrophotometer. A linear reproduction in luminance values is also visually linear. The diagram curve, see figure 9, shows the linearity among the different measured values. A linear function indicates that there is a correlation between the color chart's tone steps and the printed tone steps.

The tone values (%): 0, 5, 9, 12, 15, 18, 21, 24, 27, 30, 35 and 40 were used to create the gradations in the image adapted test chart aimed for low-key images.

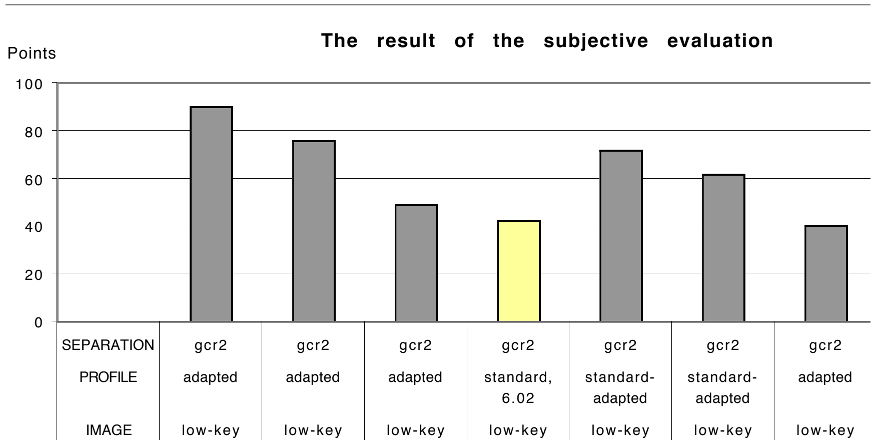

Figure 8: Observer study result. According to the observers, more details are reproduced when using the low-key adapted profile compared to the standard 6.02 profile.

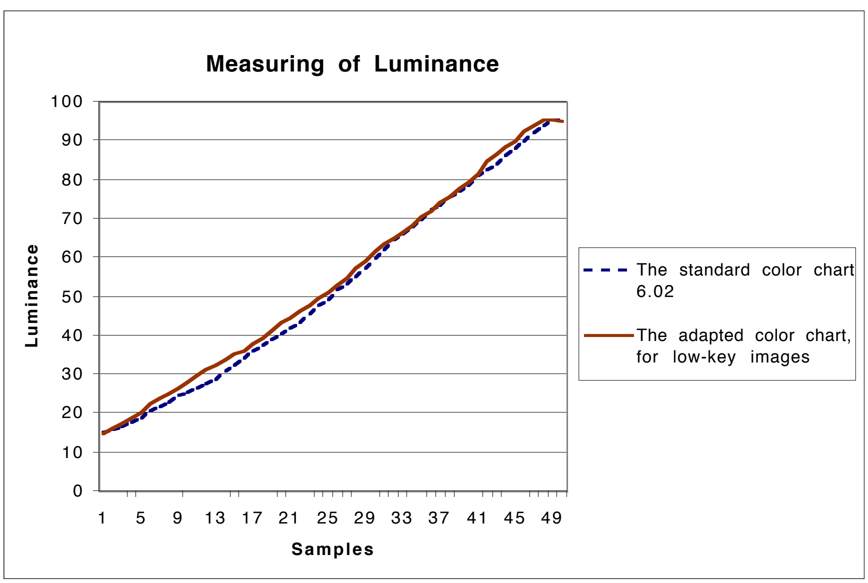

Figure 9: A linear function indicates that there is a correlation between the input gradation values and the printed tone steps measured in luminance (L).

The conclusion from this study is that a profile aimed for not only a certain output process, but also for an image category is preferable. The result is most obvious for low-key images. In this study there were no significant difference when judging image adapted profiling for hi-key images. The three categories low-key, normal-key and hi-key images gave the similar results, or as for the low-key and normal-key image, better result.

Discussion

Considering the major changes in the color chart build-up in the image adapted test charts, the result showed no huge difference among the different test charts. Even the small test charts with only a few color tiles gave a pleasing result.

The difference was more obvious the higher the tone value in the image categories. Hi-key images with small tone change from original to reproduction is not a critical category when reproducing a good tone gradation.

The hi-key image is easier to print since there is only minor dot gain to consider. An uncoated paper stock may have given a more noticeable result. The result also indicates no significant difference in reproduction of hi-key images when using different color charts for characterization.

When considering the reproduction of low-key images, the image adapted test chart gave the best result. Shadow details were better reproduced in print. This can be explained by the gradation change in the tone reproduction curve. The tone region in between 60–100% have received a larger tone spread which affects the darker tones in a positive way. The study shows that the image adapted test chart aimed at low-key images gives a better gradation in darker tones and is therefore preferable for low-key images. The image adapted color chart for hi-key images does not show an improvement in gradation compared to other standard color charts. Further studies are needed in this matter.

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