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Media Color Adaptive Gamma Correction

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Abstract

In general, most prints are printed on white paper. However, there is a little chroma level in this color, called the white. Because the color is bright enough, people may do not aware of the chroma level. However, when these prints are used as input original of a copier or a scanner, the little chroma level in this color can be detected meaningfully due to the device characteristics of the scanner and environmental factors at that time. This can lead to unintended problems such as color blur, and this color blur can be intensified especially in generation copying. Despite the fact that many scanner and copier manufacturers offer ways to reduce the chroma level of the white, color blur occurred by a variety of causes, and is therefore difficult to remove completely. The proposed correction is intended to suppress the color blur by reducing the chroma level in the white of the original used for copying or scanning. We were able to adjust the RGB gamma curve to reduce the chroma level and adjust the reduction level by analyzing the differences between the RGB channels. The experimental results demonstrate that the proposed correction provides excellent color blur reduction and is particularly effective for generation copying.

Introduction

An image can be acquired through an image input device. And the acquired image may be stored for archival purposes or may be analyzed for information gathering and may be printed at a later time. These processes have become more important in these days, where digital information is the mainstream. However, the acquired image may contain various noises due to the environment at the time. Therefore, it is necessary to appropriately correct the noises prior to the processes. In particular, since the color itself may often contain information, unintended color information that may be caused by noises should be appropriately corrected in order to prevent distortion of the information.

Printing on paper usually uses white paper. This is a method based on subtractive color model, in which information is generated by placing an appropriate amount of color in an intended shape at a specific location on white paper. It is important that the color of the paper be white because subtractive color model implements the intended color by subtracting a specific spectrum from white with all spectra. If the color of the paper is not white, it does not comply with subtractive color model, and color implementation in this case requires another color model. Color mixing models are shown in [Figure 1].

Color of a paper can be called a background color of the paper in that it becomes background of information to be printed. Unfortunately, a background color of a paper we use is not exactly white, in other words, the white color of the paper has a little chroma. This is due to technical limitations, marketing intentions, and various other reasons. However, the chroma in the background color of the paper is at a level that can comply with the subtractive color model to a certain degree. This level is not specifically defined, and is determined appropriately in the market. If the chroma in the background color of the paper exceeds that level, the consumer will judge it as colored and will try to use it for other purposes appropriate to the color.

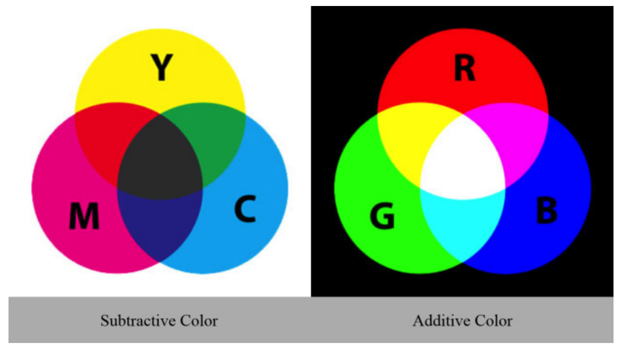


Figure 1. Color mixing models.

We collected several types of white paper and measured background color of the papers. For each of 13 types of paper, CIELab/CIELCh value was measured on the surface of multiple sheets of the clean new paper. The measuring instrument used is X-Rite SpectroEye®(Firmware Version : V2.14, Illuminant : D50, Observer Angle : 2°, White Base : Absolute). The a*b* chromaticity of the measured papers is shown in [Figure 2].

The measured values show that the range of h(CIELCh) values is about 275 to 290, which can be perceived as blue or magenta. And the range of C(CIELCh) value is 6.05 to 12.05 with an average of 8.98 and a standard deviation of 2.97, and the value itself is large and its distribution range is wide. Judging from these measurement results, the probability that the background color of the papers acquired by the image acquisition device is not recognized as white is very high. In addition, the chroma of the background color may be increased or added with an additional color due to various causes in the image acquisition process.

The chroma of the background color can be increased by the following causes.

- When additional calibrations are required for an image acquisition scanner or a document output printer.
- When noises generated during image acquisition scanner operation affect color information.
- When the chroma level of the background color is increased by image processing.

There is a variety of causes in which the chroma of the background color is increased and acquired as a meaning level of color information. Therefore, it is necessary to adaptively recognize and cope with the increased color. However, if the background color intentionally includes a particular color, it is a different issue and is excluded (e.g. colored paper).

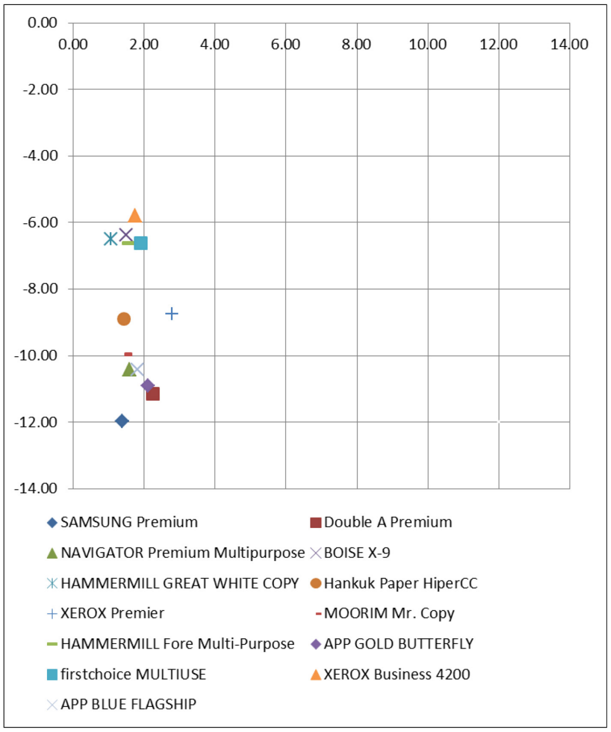


*Figure 2. The a*b* chromaticity of the measured papers.*

Conventional Method

There are various methods for correcting background color of a paper to white. Characteristics of an image acquiring device or image data itself may be corrected.

It is possible to correct background color to white by changing a white point value of a color profile. The white point value of the color profile representing characteristics of an imaging device is changed to generate a new color profile. This method modifies the characteristics of the device and requires knowledge of how to make and use a color profile. In addition, this correction is difficult to use for real-time processing because it needs to generate a color profile in advance. Background color correction method using a color profile is simplified and is shown in [Figure 3].

Background color can be corrected to white by applying a gamma curve to image data. The gamma curve is generated by analyzing the image data so as to make predicted white color white, and then applied to the image data. This correction corrects the image data itself, not characteristics of an image acquiring device, and does not require any special knowledge of image processing techniques. An example of a modified gamma curve used for background color correction is shown in [Figure 4].

Both methods of correcting characteristics of an imaging device or correcting image data may result in a change in color balance. It also accompanies with background color removal effect that occurs when an predicted color is corrected to white. In particular, since degree of loss of image data depends on policy of background color removal, it is necessary to adjust strength of background color removal adaptively according to type of original.

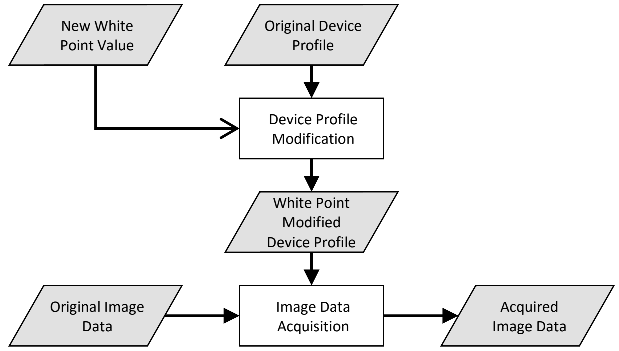
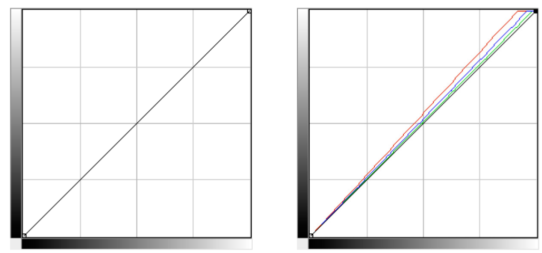


Figure 3. Simplified background color correction method using a color profile.



(a) Default curve

(b) Modified curve for correcting to white

Figure 4. An example of gamma curve for modification to correct background color.

Proposed Method

The proposed correction is to acquire more accurate color when acquiring an image through an image acquisition device. Chroma level in background color of paper, which is an original medium of an image to be acquired, may be increased or assigned due to various causes during image acquisition process. The purpose of the proposed correction is to maximize the suppression of the increased or assigned chroma level. In addition, it can be applied to real-time processing, and strength of background color removal effect can be adjusted adaptively.

The proposed correction directly corrects image data after acquiring the image data as shown in [Figure 5]. A part or all of the image data is obtained and analyzed, and then RGB values that are predicted to be white are selected. The selected RGB value is analyzed to determine correction level. Gamma curve is generated based on the determined correction level and then applied to the image data to perform the correction.

Step 1 : Pre-acquiring image data

In order to determine whether background color of paper is white, a part or all of original image data must be acquired. However, analyzing entire image data in real-time processing may be accompanied with performance degradation. The proposed correction uses the amount of initial image data acquired during the operation of the scanner as the analysis data, in view of the fact that there is almost no document information in the frame of a document. The function of loss of color information such as background color removal should not be applied to the pre-acquired image data. An example of image data pre-acquisition area is shown in [Figure 6].

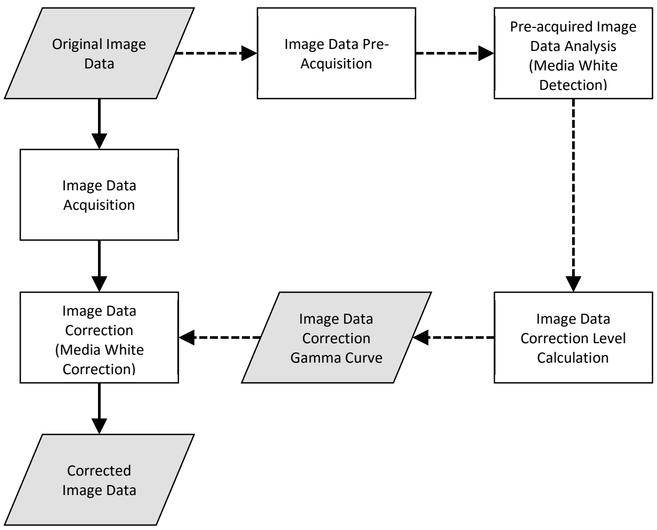
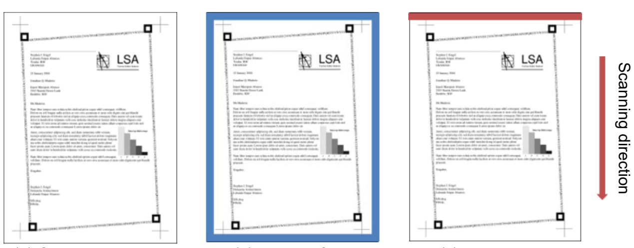


Figure 5. Workflow of the proposed correction.



(a) Original document (b) Margin of the document (c) Pre-acquisition area

Figure 6. An example of pre-acquisition area.

Step 2 : Analyzing the pre-acquired image data

The histogram of the pre-acquired image data is analyzed and the RGB value to be corrected to white is selected. For efficiency of real-time processing, the histogram is analyzed independently for each channel with only the initial image data pre-acquired by the scanner. The amount of image data predicted to be corrected to white among pre-acquired image data is highly variable. If the amount of image data predicted to be corrected to white is very less than other color, the selected RGB value may be very dark, which may result in erasing most of the image. Therefore, additional analysis conditions are required in order to prevent such erroneous selection of RGB values. In order to increase the efficiency of the analysis, if the range of the histogram to be analyzed is limited to a bright RGB region, the additional analysis condition is not necessary and the selection of the wrong RGB value can be prevented. In the case of an 8-bit image, the histogram analysis is performed for a range corresponding to 8 from white among 256 gradations of each channel. For each channel, a value with the largest amount of image data within the range of analysis after processing moving sum will be selected. Each selected channel value can be combined to select the correction level RGB value. An example of selecting the analysis range and RGB values is shown in [Figure 7].

Level	247	248	249	250	251	252	253	254	255	Max
Red	1,959	1,895	2,007	2,543	4,344	5,996	5,966	17,108	9,284	17,108
Green	583	596	1,452	1,367	1,733	9,017	329	376	0	9,017
Blue	320	344	370	199	259	1,255	1,925	678	8,860	8,860

(a) Combination of selected RGB values : (254, 252, 255)

Level		248	249	250	251	252	253	254	255	Max
Red		5,861	6,445	8,894	12,883	16,306	29,070	32,358	26,392	32,358
Green		2,631	3,415	4,552	12,117	11,079	9,722	705	376	12,117
Blue		1,034	913	828	1,713	3,439	3,858	11,463	9,538	11,463

(b) Combination of selected RGB values after moving sum : (254, 251, 254)

Figure 7. An example of selecting the analysis range and RGB values

$$msh_{Red}(i) = \sum_{j=i-1}^{i+1} h_{Red}(j) \quad (1)$$

$$msh_{Green}(i) = \sum_{j=i-1}^{i+1} h_{Green}(j) \quad (2)$$

$$msh_{Blue}(i) = \sum_{j=i-1}^{i+1} h_{Blue}(j) \quad (3)$$

$$r = [i | max(msh_{Red}(i))] \quad (4)$$

$$g = [i | max(msh_{Green}(i))] \quad (5)$$

$$b = [i | max(msh_{Blue}(i))] \quad (6)$$

$$RGB_{Selected} = (r, g, b) \quad (7)$$

$$where\ (255 - 8) < i \leq 255, i \in Z$$

where, $h_{Channel}$ is image data histogram of the channel, $msh_{Channel}$ is moving summed image data histogram of the channel, i is histogram index.

Step 3 : Calculating a correction level

Each selected RGB value is used as the background color removal level according to the background color removal policy. There are three types of the background color removal policy : Min / Mid / Max. The largest value among the three channel values is applied when minimizing background color removal and the smallest value among them is applied when maximizing background color removal. If the original image data input to the image acquisition device is text-oriented, it is necessary to sufficiently remove the background color because of improving readability of text. Conversely, if the original image data is photograph-oriented, it is necessary to minimize background color removal for reasons such as an improved detail representation. Alternatively, the background color removal policy may vary depending on user's personal preference. If the background color removal policy is [Min], the channel having the largest value among the selected RGB values is fixed and the values of the remaining two channels are changed. If the background color removal policy is [Max], the channel having the smallest value among the selected RGB values is fixed and the values of the remaining two channels are changed. If the background color removal policy is [Mid], the channel having a middle value among the selected RGB values is fixed and the values of the remaining two channels are changed. The background color removal policy is input separately from the image data acquisition process. If the selected RGB values in each channel are denoted as r, g, and b, the correction level selection according to background color removal policy can be shown in [Figure 8].

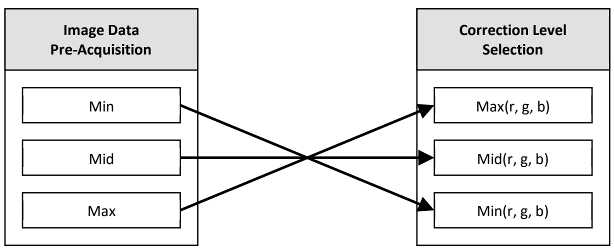


Figure 8. The correction level selection according to background color removal policy.

Step 4 : Generating gamma curves

Values of the channel to be changed are calculated by referring to the selected RGB value. The selected RGB values are denoted as (r, g, b). The maximum value among the channel values is denoted as max(r, g, b). The minimum value among the channel values is denoted as min(r, g, b). The middle value among the channel values is denoted as mid(r, g, b). If the background color removal policy is [Min], the channel having the maximum channel value is fixed and the remaining two channels are changed into the maximum value channel, so that it can be expressed as (9)(10)(11)(12). If the background color removal policy is [Max], the channel having the minimum channel value is fixed and the remaining two channels are changed into the minimum value channel, so that it can be expressed as (13)(14)(15)(16). If the background color removal policy is [Mid], the channel having the middle channel value is fixed and the remaining two channels are changed into the middle value channel, so that it can be expressed as (17)(18)(19)(20). The result values of each equation are corrected within the range of the channel scale. There gamma curves are generated for each channel according to these formulas and applied to the image data. An example of the gamma curve generating according to these equations is shown in [Figure 9].

Case : $[Background\ Removal\ Policy]$ is $[Max]$

$$f_{min}(x) = \frac{min(r,g,b)}{255}x \tag{9}$$

$$\grave{f}_{min} = f_{min}(x) \tag{10}$$

$$\grave{f}_{mid} = \frac{min(r,g,b)}{mid(r,g,b)} f_{mid}(x) \tag{11}$$

$$\grave{f}_{max} = \frac{min(r,g,b)}{max(r,g,b)} f_{max}(x) \tag{12}$$

Case : $[Background\ Removal\ Policy]$ is $[Mid]$

$$f_{mid}(x) = \frac{mid(r,g,b)}{255}x \tag{13}$$

$$\grave{f}_{min} = \frac{mid(r,g,b)}{min(r,g,b)} f_{min}(x), \tag{14}$$

$$\grave{f}_{mid} = f_{mid}(x) \tag{15}$$

$$\grave{f}_{max} = \frac{mid(r,g,b)}{max(r,g,b)} f_{max}(x) \tag{16}$$

Case : $[Background\ Removal\ Policy]$ is $[Min]$

$$f_{max}(x) = \frac{max(r,g,b)}{255}x \tag{17}$$

$$\grave{f}_{min} = \frac{max(r,g,b)}{min(r,g,b)} f_{min}(x), \tag{18}$$

$$\grave{f}_{mid} = \frac{max(r,g,b)}{mid(r,g,b)} f_{mid}(x) \tag{19}$$

$$\grave{f}_{max} = f_{max}(x) \tag{20}$$

$$where, 0 \leq x < 256, x \in Z$$

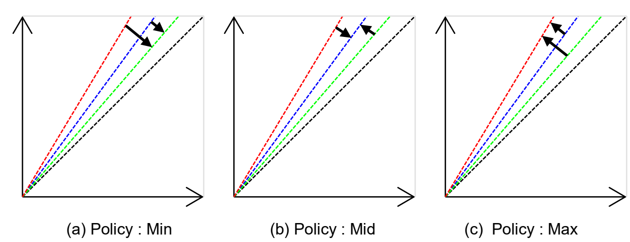


Figure 9. An example of the gamma curve generating.

Experimental Results

We applied the proposed correction to the copy job. The machine used for the copy job is an A3 copier equipped with a scanner using a CCD sensor. We set the machine to have a slightly bluer-shift than the original one used for copying. The background color removal policy was [Mid]. The paper used for printing and copying is Samsung Premium(75 grams per square meter). As shown in [Figure 2], this paper has a CIELab value of (93.02, 1.37, -11.97) when measured with a colorimeter. The color change of the copy result was visually confirmed. In order to more easily confirm the color change of the copying result, generation copy was performed up to the fifth. First, we printed a grayscale document. Then we made a color copy of the printed document as a copy original, and the copy that we obtained was labeled the first copy. We copied again the first copy as a copy original, and the copy that we obtained was labeled the second copy. We continued to get up to the fifth copy, and then we checked how the color blur is changed.

The results of the proposed correction are shown in [Figure 10]. Comparing the two results, it can be confirmed that the intentional blue blurring phenomenon is remarkably suppressed. Especially, as the number of generation copy increases, the overall color blur accumulation occurs, but the color accumulation supper-

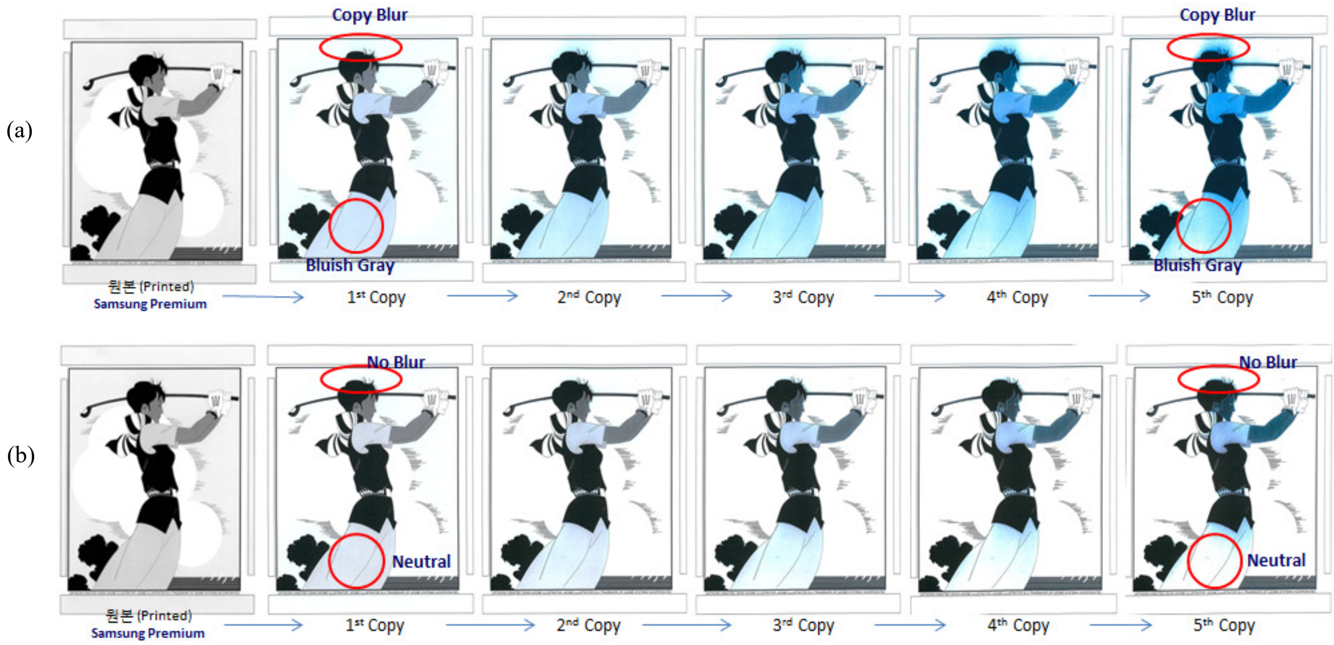


Figure 10. (a) The result without the proposed correction.
(b) The result with the proposed correction.

-ession becomes prominent in the background color region which is similar to white.

The results of the proposed correction are shown in [Figure 10]. Comparing the two results, it can be confirmed that the intentional blue blurring phenomenon is remarkably suppressed. Especially, as the number of generation copy increases, the overall color blur accumulation occurs, but the color accumulation suppression becomes prominent in the background color region which is similar to white.

Conclusion

The proposed correction is for the case of acquiring image data using an image acquisition device where the original image to be acquired has a white background. Then, it can be summarized as follows.

It corrects small amount of chroma level present in white, which is background color of the original document, as close to white as possible. This color correction can be a complement to color calibration error of an original document output device, color calibration error of an image acquisition device, chroma level changes emphasized during image acquisition processing, or other unintended increases in chroma level.

It is configured for real-time operation. This correction only analyzes the initial part of the acquired image, immediately detects the color change of the original document, and creates and applies gamma curves to prevent image processing slowdowns.

In addition, it is possible to select the background color removal level in three steps. And especially it is effective to suppress the unintended color accumulation in the generation copy where the color accumulation occurs.

Furthermore

If the background color removal level is set for one channel among RGB selected and the remaining two channels are changed into the channel, the color balance may vary depending on the situation. Even if the issue does not noticeable well because the proposed correction is aimed at a small amount of color correction, a more stable technical complement to the color balance change is needed.

References

[1] E.H. Land, "The Retinex Theory of Color Vision", Scientific American, Pages:108-129, 1977.

[2] Buchsbaum, G., "A spatial processor model for object colour perception", Journal of The Franklin Institute 310, 1(July), Pages:1–26, 1980.

[3] D.A. Forsyth, "A Novel Algorithm for Color Constancy", Int. J. of Computer Vision, 5:1, 5-36, 1990.

[4] Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing", Addison-Wesley Publishing Co., Inc., 1993.

[5] Richard Patterson, "Gamma Correction and Tone Reproduction in Scanned Photographic Images", SMPTE Journals & Magazines, Pages 377–385, June 1994.

[6] G. Finlayson, "Color in Perspective", IEEE Trans. PAMI, 18 (10), pp. 1034-1038, 1996.

[7] B. Funt, V. Cardei, and K. Barnard, "Learning Color Constancy", Proc Fourth Color Imaging Conf., pp. 58-60, Scottsdale, Arizona, November 1996.

[8] Poynton, C.A. "A Technical Introduction to Digital Video", John Wiley & Sons, 1996.

[9] Barnard, K., Finlayson, G. D., and Funt, B. V, "Color constancy for scenes with varying illumination", Computer Vision and Image Understanding 65, 2 (Mar.), Pages:311–321, 1997.

[10] Sharma, G., Trussell, H.J. "Digital Color Imaging", IEEE Trans. on Image Processing 6 (7), Pages:901–932, 1997.

[11] Henry R. Kang, "Color Technology for Electronic Imaging Devices", SPIE Press, 1997.

[12] Wilfried Kubinger, Markus Vincze, Minu Ayromlou, "The role of gamma correction in colour image processing", 9th European Signal Processing Conference (EUSIPCO 1998), Pages:1-4, 1998.

[13] C. Poynton, "The Rehabilitation of Gamma", B.E. Rogowitz and T.N. Pappas (eds.), Proc. of SPIE 3299, pp. 232-249, Bellingham, WA.: SPIE, 1998.

[14] V. Cardei, B. Funt and M. Brockington, "Issues in Color Correction of Images from Unknown Origins", CSCS'12, Bucharest, May, 1999.

[15] Finlayson, G. D., and Hordley, S. D, "Improving gamut mapping color constancy", IEEE Transactions on Image, Processing 9, 10 (Oct.), Pages:1774–1783, 2000.

[16] Wilhelm Burger and Mark J. Burge, Digital Image Processing, Springer, 2008.

[17] University of Utah, CS 4640 "Image Processing Basics", Spring 2012.

[18] Rutgers University, CS 334, "Introduction to Imaging and Multimedia", Fall 2012.

[19] Alexis Van Hurkman, "Color Correction Handbook: Professional Techniques for Video and Cinema", Peachpit Press, 2014.

[20] http://s-isles1114-dc.blogspot.kr/2011/11/colour-lecture-1.html

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