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Automatic image enhancement for under-exposed, over-exposed, or backlit images

Jaemin Shin, Hyunsoo Oh, Kyeongman Kim, Kimin Kang
HP Printing Korea, 129, Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea, 16677
{ jae-min.shin, hyunsoo.oh, kyeongman.kim, kimin.kang } @hp.com

Abstract
Unfortunately, images acquired by users from image acquiring devices like cameras could be under-exposed, over-exposed, or backlit. These under-exposed, over-exposed, or backlit images are not suitable for recognizing the information contained in the images. In this paper, we propose a new technique which corrects the brightness of already acquired images from image acquiring devices. This technique divides the image area to determine the state of brightness and operates according to the results of the state analysis without any threshold or magic value. It effectively corrects the brightness of under-exposed, over-exposed, or backlit images using only image data analysis.

Background
With the rapid spread of smartphones over the past decade, taking pictures has become a part of our daily life. Nowadays, a lot of people produce so many photos every day more than the past. And growth of social media has accelerated the lifestyle taking pictures.

However, the fact that taking pictures is now always around us does not mean that all the pictures are produced in high quality. The lighting when taking pictures is not always optimized. While many techniques have been provided to solve this problem, it is not possible to cover all situations. So, we thought that a better algorithm for a lot of different situations is needed.

There are three representative cases for having bad brightness image. A histogram example of an under-exposed image is shown in Figure 1. In this histogram, most of the data exist in the dark level and there is a little data in the middle level. Since there is little data in the bright level, it is very difficult to recognize the subject in the image.

And another histogram example of an over-exposed image is shown in Figure 2. In this histogram, most of the data exist in the bright level and there is a little data in the middle level. Contrary to the histogram of the under-exposed image, there is little data in the dark level, so that the shape and the texture of the subject are difficult to be represented properly.

A final histogram example is shown in Figure 3. It is a backlit image that the light source is present in the direction where the subject is located, and the surface of the subject is represented as a dark level. So, the outline of the subject has a strong contrast, but the texture of the subject's surface is not properly represented.

Several representative applications having automatic brightness correction have been tested, and the result of automatic brightness correction was compared. The four applications that were rated by users as having excellent automatic brightness correction were selected for the test. The images for testing were obtained using Google Image Search.

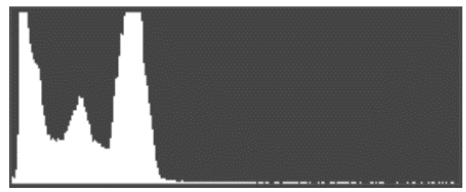

Figure 1. A histogram example of an under-exposed image.

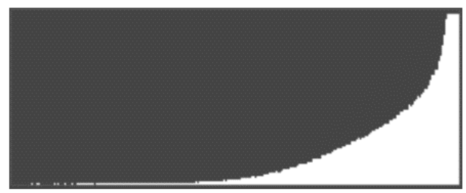

Figure 2. A histogram example of an over-exposed image.

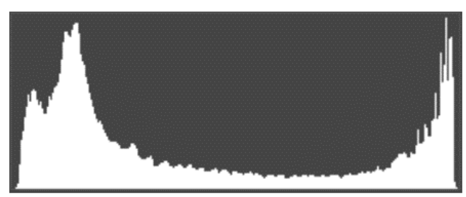

Figure 3. A histogram example of a backlit image.

There is a test result in Table 1. App #1 and App #2 corrected the brightness well for under-exposed or over-exposed images. However, these two applications did not adequately correct the brightness of backlit images. Especially, App #1 has a problem that the application stops when a specific backlit image is loaded. App #3 also did not improve the brightness of backlit images sufficiently. Moreover, App #3 did not improve the brightness of under-exposed images properly. Finally, App #4 showed the opposite performance from the three applications mentioned above. It has a poor correction for over-exposed images but has a good brightness correction for under-exposed or backlit images.

Based on these comparative test results, an algorithm that automatically corrects brightness for under-exposed, over-exposed, or backlit images has been developed. The goal of the developed algorithm is not to work better for a certain brightness status, but to achieve an equal or better result than other algorithms in all brightness ones.

Table 1. The comparison of automatic brightness correction

	App #1	App #2	App #3	App #4
Under-exposed	Good	Good	N/G	Good
Over-exposed	Good	Good	Good	N/G
Backlit	N/G	N/G	N/G	Good

Previous Methods

Prior to the development of a new automatic brightness correction method, we reviewed some papers to gather technology items that are suitable and useful to our algorithm. We have selected four papers that are consistent with our goal of development, and the list of the selected papers is as follows.

- Quoc Kien Vuong, "A New Auto Exposure System to Detect High Dynamic Range Conditions Using CMOS Technology", 2008
- Jie Liu, "Study of automatic exposure algorithm based on HD ip camera", 2010
- Zhang Haifeng, "A New Algorithm for Auto-Exposure Based on the Analogy Histogram", 2011
- Tao Jiang, "Multiple templates auto exposure control based on luminance histogram for onboard camera", 2011

The Reference Paper #1

The first paper is "A New Auto Exposure System to Detect High Dynamic Range Conditions Using CMOS Technology" by Quoc Kien Vuong in 2008. This method is to determine the exposure to take a video. It is different from our method, which is a post-processing method that automatically corrects the brightness of still images. But in this paper, they use a difference between a histogram mean value and a histogram median value. The concept of these values is in Figure 4.

The Reference Paper #2

The second paper is "Study of automatic exposure algorithm based on HD IP camera" by Jie Liu in 2010. This method is for IP cameras, so motion detection is required for video data. Thus, they divide an entire image area into the number of equal-sized parts. Also, they use a histogram average value for each divided area the whole area.

The Reference Paper #3

The third paper is "A New Algorithm for Auto-Exposure Based on the Analogy Histogram" by Zhang Haifeng in 2011. In this paper, two threshold values are extracted from image data. From these thresholds, we can derive a concept of dividing an entire dynamic range into low, middle, and high levels. In Figure 5, the concept of the division is shown. They introduce that Threshold T_{low} is a lower limit of an image histogram, and Threshold T_{high} is an upper limit of the image histogram. From this concept, we derive a concept of dividing a histogram level into three.

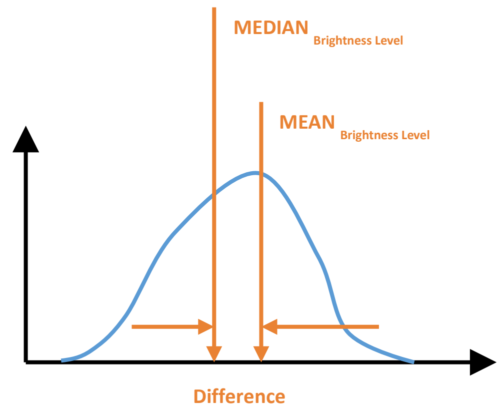

Figure 4. Key factors in the reference paper #1

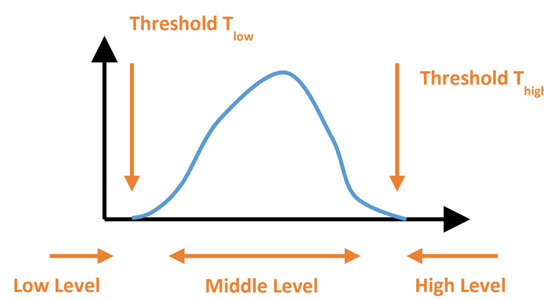

Figure 5. Key factors in the reference paper #3

The Reference Paper #4

The last paper is "Multiple templates auto exposure control based on luminance histogram for onboard camera" by Tao Jiang in 2011. In this paper, they divide an image into nine parts like the paper mentioned above. But the purpose of dividing is different. It is to determine the brightness state of the input image data. And they use a histogram average value of each divided part.

The Proposed Method

By using the technical items identified in the four papers mentioned above, we have developed a method for automatically correcting the brightness of images in a simple and effective way.

The proposed method consists of 10 steps. Although there are many steps in this method, the processing that is done at each step is simple. All steps are shown in Figure 6.

Step #1: Histogram Stretching

After extracting a histogram of a brightness data from an input image, the histogram data is stretched to improve the dynamic range of the histogram with a clipping value 0.1% level. This is general processing.

Step #2: Image Division into 9 Parts

Divide an entire image area into three horizontal and three vertical parts with equal size.

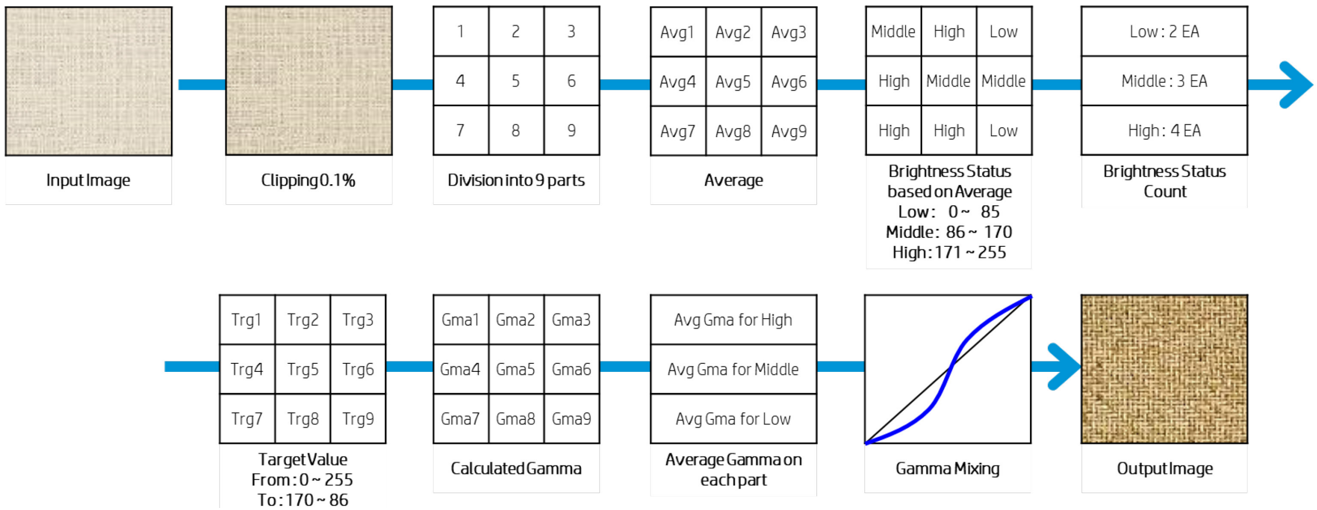

Figure 6. All steps of the proposed method

Step #3: Average Value Calculation for each Part

Calculate the histogram average values of each part.

Step #4: Brightness Status Determination

The histogram average values obtained from each part are used to determine the brightness status of each part. The range for a brightness status determination is as follows.

Table 2. The Range for a Brightness Status Determination

	From	To
Low	0	85
Middle	86	170
High	171	255

Step #5: The Number of each Brightness Status

Count the number of each brightness status.

Step #6: The Target Value Calculation

Calculate target values for each part. Target values for each part can be calculated from Eq. (1). Eq. (1) means taking a reverse value based on the mean value. For example, if the average value of a specific part is 230, it indicates a sufficiently bright state. Therefore, the target value is set to (255-230) = 25 and will uses for correcting to be sufficiently dark. As another example, if the average of the part is 127 than the target value is set to (255-127) = 128 by Eq. (1), and the brightness correction hardly occurs. However, when this formula is applied to the entire dynamic range, there may arise a problem of overcompensation. Therefore, in practice, certain ranges close to black and white should be excluded. We used 15/16 of the full dynamic range.

$$Target\ Value_{Each\ Part} = (255 - Average\ Value_{Each\ Part}) \quad (1)$$

Step #7: The Compensation Gamma Value Calculation

Calculate compensation gamma values for each part. The compensation gamma values for each part can be calculated from Eq. (2). Eq. (2) produces an available gamma value by combining the target value and the average value. A range of gamma values could be set to prevent excessive compensation.

$$Gamma\ Value_{Each\ Part} = \frac{\log(Target\ Value_{Each\ Part})}{\log(Average\ Value_{Each\ Part})} \quad (2)$$

Step #8: The Average of Gamma Values Calculation for each Level

The calculated gamma values are averaged to obtain gamma values for each brightness level. If there is no gamma value for a certain level, it will be set to 1.0.

Step #9: Gamma Curve Generation through Gamma Value Mixing

The gamma values obtained at each level should be fully applied to that level. Relatively, it should be applied less at different levels. Therefore, a compensation curve is created by applying the weightings shown in Figure 7.

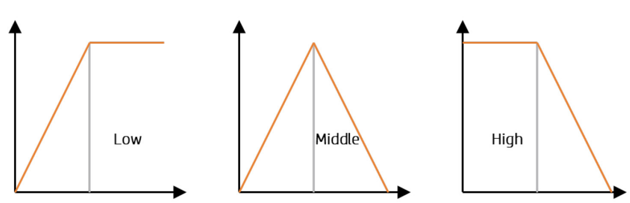

Figure 7. The curves for weighting values for a gamma mixing

Step #10: Brightness Compensation

Apply the compensation curve to the image.

Experimental Results

The experimental results are compared against the result of the four applications mentioned above using under-exposed, over-exposed, and backlight images. Experimental results are shown in Table 3.

Under-exposed Images

Compared with other existing methods, in the car image, the proposed method improves the side of the vehicle and the walls of the house better, and in the mountain image, improves the texture of the mountain better.

Over-exposed Images

Compared with other methods, the proposed method produces similar results.

Backlit Images

The proposed method shows improved results compared with other methods. In the flower image, the texture and contrast are better than others. And the pink jacket image is improved brighter.

Summary

The proposed method automatically improves the brightness of still images. This method works by analyzing image data only without any threshold or magic value. The core algorithm of this method is simple and does not cause performance degradation. And it can obtain improved results compared to existing commercial algorithms. This brightness correction works more for dark images. And it works as good as the existing commercial algorithms for bright images. It is because of the gamma curve characteristics that use gamma values for compensation.

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Author Biography

JAEMIN SHIN received his B.S. and M.S. degree in Electronic Engineering from Kwangwoon University, South Korea, in 1999 and 2006. From 2006 to 2017, he was a R&D engineer at Samsung Electronics Co. Ltd., Suwon, South Korea, where he worked on color management/enhancement for printer and copier. Since November 2017, he has been with HP Printing Korea (HP Inc.), Suwon, South Korea, developing algorithms for color management/enhancement systems. His research interests include color management systems, color pipeline, and color enhancement.

HYUNSOO OH received his B.S. and M.S degrees in Dept. of Graphic Arts Information Engineering from Pukyoung National University, South Korea, in 1997 and 2001, respectively. From 2000 to 2003, he was a software engineer at on KoreaC4 Co. Ltd., Seoul, South Korea, where he has developed Software RIP's color management platform and color matching algorithm for Hi-Fi Printers. From 2003 to 2016, he has been with Samsung Electronics Co. Ltd., Suwon, South Korea, developed color management algorithms for the copier machines. Since November 2016, he has joined HP Printing Korea Co. Ltd., Suwon, South Korea, developing color management solutions and algorithms for enterprise devices.

KYEONGMAN KIM received his BS, MS, and PhD degrees from Kyungpook National University in 1993, 1995, and 1999, respectively, all in electronic engineering. From August 1998 to October 2016, he joined in the Printer R&D Team, Digital Printing Business Division, Samsung Electronics, Co., Ltd, Suwon, Korea, where he developed color imaging platform and its related SW / FW architecture, algorithms, and solutions. Since November 2017, he has been in Imaging Lab in Hewlett Packard Korea Co. Ltd, developing color processing algorithms for the copier machines. His research interests are digital signal processing and its ASIC processor design, photo enhancement algorithm, color compression, and processing with color management system for the printer and multi-functional copier machines.

KIMIN KANG received his PhD degree in Electrical Engineering from Inha University, South Korea, in 2001. He started to research and develop the image processing algorithms for digital printer in Samsung Electronics from 2002. He had been architecting the image pipeline and developing the enhancement algorithms for ASIC and SW applications. Now, he is leading the imaging technologies for printers and scanners in HP Printing Korea.

Table 3. Experimental Results