Improved dynamic range of the camera image by using double-exposure image processing method for mobile phone cameras

Won-Woo Jang, Boo-Dong Kwak, Joo-Young Ha, Bong-Soon Kang and Gi-Dong Lee *Member, KIMICS*

Abstract—In this paper, we propose the improvement method of the camera images regardless of exposure environments. By using a double-exposure method, we could improve camera images with clear recognition. We applied the improvement method on the mobile phone. For the feasibility of the proposed algorithm, we compared simulated camera images with the proposed method to conventional images by using auto-exposure image. Experimental results are also shown in this paper.

Index Terms— Dynamic range, double exposure, mobile phone cameras

I. INTRODUCTION

The cameras create the video and photography by gathering a reflected light from the objects through the lens of cameras and exposing the reflected light to the image sensor of the cameras [1]. Despite of the same subject for video and photography, according to state of the illuminant of the environment, it is possible to change the quality and whole impression of the video and photography taken by cameras. Moreover, there are a number of scenes, the eyes of the person can be visible to the scenes but the cameras are still impossible to pick up them. The real world shows the scenes intensities ranging from starlit to white snow in sunlight [3].

When taking picture with outdoor or specific indoor scenes, the dynamic range (DR), which refers to the ratio of the highest and lowest level of light intensities, is usually higher than the range of most image sensors [2,4-5]. Although high quality image sensors have larger DR, most consumer imaging systems have narrower exposure latitude than color negative films [3]. The standard video formats (RGB or YCbCr) can support only lucidity information with 0-255 range [6], it is impossible to get a proper representation of images under the extremely environment. In order to solve the problem, the method is to take multiple images in the same scenes with different exposure time for getting more luminance information and then fuse them into single image [1,4,7-9].

In this paper, we propose a double-exposure image processing method to increase the DR of the mobile camera phones. By using the proposed method, we can increase the recognition ability for the camera image. We compared simulated digital still camera images with the proposed method to normal exposure images.

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II. Proposed Method

Figure 1 shows the proposed processing to obtain images with an enhanced dynamic range. The system uses a general Auto Exposure (AE) algorithm based on averaged luminance value per a scene, and determines an exposure value (EV) to take two differently exposed images of short exposure (SE EV×1/N) image and long exposure (LE: EV×N) image.

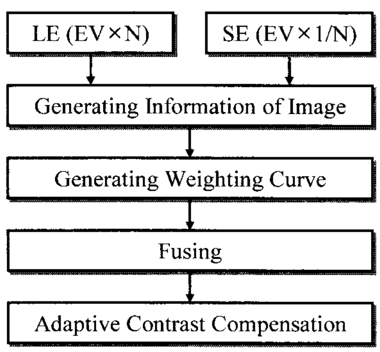

Fig.1 The proposed processing to obtain images with an enhanced dynamic range

The Generating Information of Image step obtains each maximum, minimum, and averaged luminance value from SE and LE image. We also divide SE and LE image into 12×9 sub-regions and extract each maximum, minimum, and averaged luminance value of each sub-region. The Generating Weighting Curve step generates the curves with typical two lookup tables (size: 1×256) to describe fine image details/textures and to prevent over-saturated parts in resulting images. We employ that one of two lookup tables, *SETRemapLUT*, remaps the original luminance levels (0~255) of SE image as shown in Fig. 2. We calculate four points by using following equations:

$$SETRegionTh = (SETImgAvg + WinSETImgMax)/2 \quad (1)$$
$$SETRegionTl = (SETImgAvg + WinSETImgMin)/2 \quad (2)$$

where *SETImgAvg* represents the averaged luminance value from SE image. *WinSETImgMax* and *WinSETImgMin* represent the maximum and minimum values from the averaged luminance values of sub-regions of SE image.

$$SETIndex1 = SETRegionTh + LETImgAvg - SETImgAvg \quad (3)$$
$$SETIndex2 = SETImgMax + LETImgAvg - SETImgAvg \quad (4)$$

where *SETImgAvg* and *SETImgMax* represent the averaged and maximum luminance value from SE image. *LETImgAvg* represents the averaged luminance value from LE image.

The other table, *LETalphaLUT*, controls the weight of the LE image as shown in Fig. 3. We also calculate three points by using following equations:

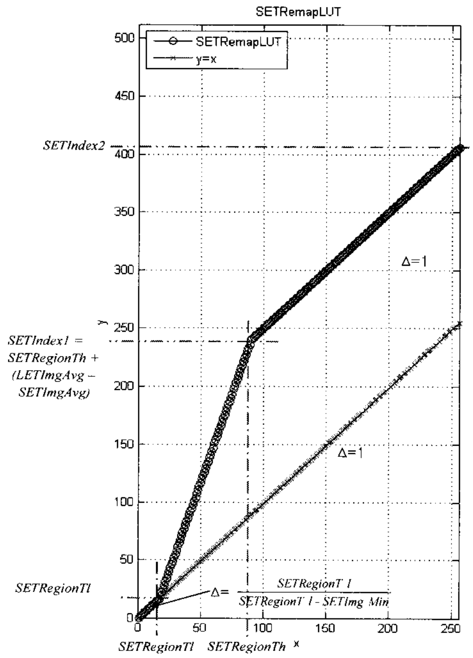

Fig. 2 Lookup table for SE image: *SETRemapLUT*

$$LETRegionTh = (LETImgAvg + WinLETImgMax)/2 \quad (5)$$
$$LETRegionTl = (LETImgAvg + WinLETImgMin)/2 \quad (6)$$
$$alphaMax = SETRegionTh + LETRegionTh \quad (7)$$

where *LETImgAvg* represents the averaged luminance value from LE image. *WinLETImgMax* and *WinLETImgMin* represent the maximum and minimum values from the averaged luminance values of sub-regions of LE image.

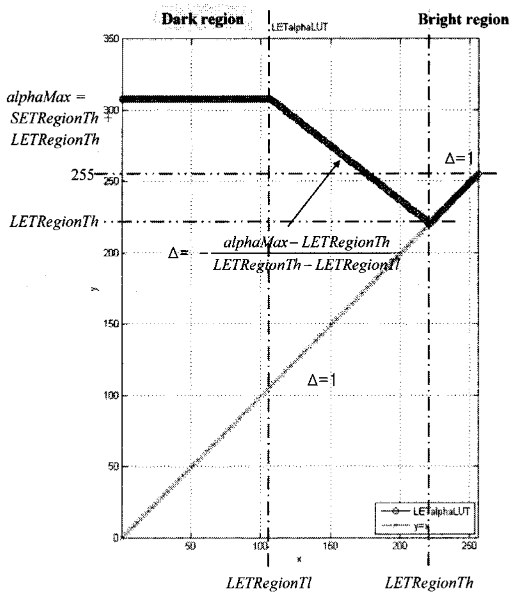

Fig. 3 Lookup table for LE image: *LETalphaLUT*

The Fusing step fuses two images by using two curves in Eq. (8) [9].

$$F_{RGB} = SE_{RGB} \times (\alpha \times SE_{LUT}) + LE_{RGB} \times (\beta \times LE_{LUT} + \gamma) \quad (8)$$

where F_{RGB}, SE_{RGB}, and LE_{RGB} denote original fused image data, SE image data, and LE image data. SE_{LUT} and LE_{LUT} represent two lookup tables that are generated from the Curves Generation step. α, β, and γ present constants. The Adaptive Contrast Compensation step consists of the local contrast enhancement and the histogram equalization. In order to enhance the local contrast of original fused image, we apply a brightness weight to the original fused image in inversely proportional to the average luminance values of the sub-regions of the LE image. In the histogram equalization, we compress the bit size of original fused image to the bit size of final fused image. We apply the low population suppression to the histogram information from the original fused image and then subtract the index of the histogram with smaller than 0.078 percent of the size of the original fused image.

III. SYSTEM ARCHITECTURE

Figure 4 shows the simplified block diagram of the improved DR system that can be used in mobile applications. The DR_system block employs the abovementioned proposed method, and controls the flame memory in order to save LE and SE images because the proposal algorithm basically requires two images with each other different luminous intensity. The DR_sensor_cont block generates the two different

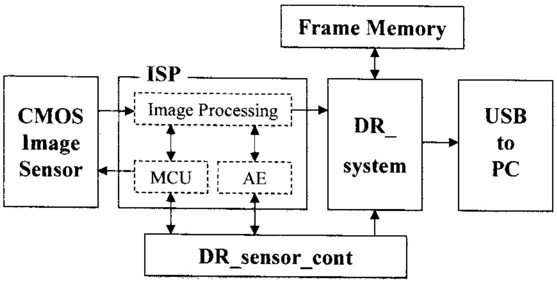

Fig. 4 Simplified block diagram of the improved DR system

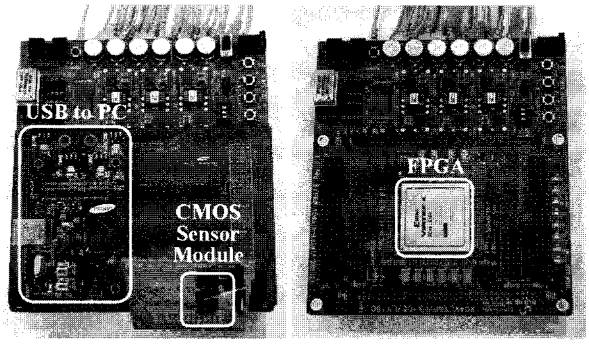

Fig. 5 Demonstration board

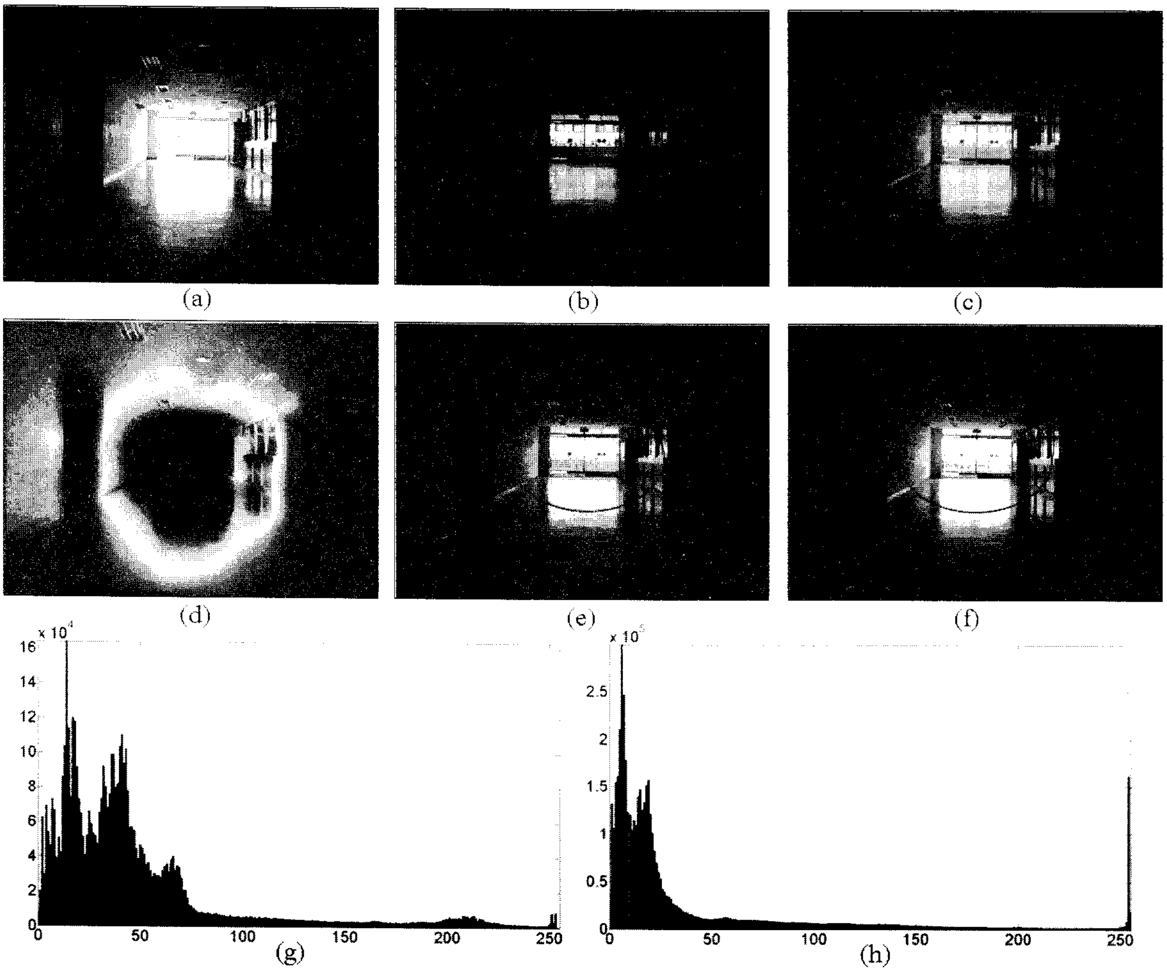

Fig. 6. Simulation results, (a) long exposure, (b) short exposure, (c) original fused image without Adaptive Contrast Compensation, (d) distribution of brightness weight for local contrast enhancement, (e) final fused image, (f) normal exposure, (g) histogram of the luminance of the final fused image, and (h) histogram of the luminance of the normal exposure

exposure time to control the electronic rolling shutter of the CMOS Image Sensor through the MCU (Micro Controller Unit) block. The AE block is continually capturing the images except of the LE and SE images, calculates the appropriate exposure level. The Image Processing compensates the digitized raw data and derives RGB values from the Bayer signals captured from the CMOS sensor lens. It also conducts various colors processing such as color matrix, brightness, gamma processing, and so on. The proposed system is designed by using Verilog-HDL models and is verified by using the Synopsys. The models are synthesized into gates to observe the hardware complexity by using the Synopsys synthesizer with the TSMC 0.25-μm ASIC library. Figure 5 shows two PCB verification boards for the proposed system. There are three major building devices of a CMOS sensor for mobile phone cameras, a FPGA device, and a USB-to-PC interface. Captured image data are processed by FPGA device, and then the processed data are transferred to the display device by using the USB-to PC.

Table 1 System Gate Count

Module Name	Gate Count	Min Timing [MHz]
DR_System	105,887	76.04
DR_sensor_cont	7,256	75.52
Total	113,143	77.34

IV. SIMULATION AND EXPERIMENTAL RESULTS

For performance of the proposed processing, Fig. 6 shows simulations which were executed with the compound images (2592×1944) captured from the consumer digital still camera. Figure 6(a) and (b) long (EV×2) and short (EV×1/2) exposure times in which some pixels are over/under-exposed. Figure 6(c) shows the original fused image with bigger than 8-bit R, G, and B data. Figure 6(d) shows the distribution of the brightness weight. The more the color of distribution is close to red, the stronger the brightness weight is. We apply Fig. 6(d) and the histogram equalization to Fig. 6(c) for local contrast enhancement and obtain the final fused image as shown in Fig. 6(e). Figure 6(f) is taken with normal (EV) exposure times. Therefore, the final fused image simultaneously captures more information of the outdoor (windows of the opposite building and small trees in the flower bed) scene than that of the normal exposure. Figure 6(g) and 6(h) show the histograms of the luminance of the Fig. 6(e) and Fig. 6(f). The luminance values of the Fig. 6(g) were distributed widely range from 0 and 75, while those of the Fig. 5(h) were distributed over the range from 0 to 30.

Figure 7 shows compound images (768×576) captured from the verification board. In the Scene #1, Fig. 7(a) and (b) are captured with normal and the final fused image. The final fused image shown in Fig. 7(b) simultaneously captures more information of the two color checkers under the window rail than those of the normal exposure. There are luminance values of three points, ①: 16,675 lux, ②: 64.8 lux, ③: 35.8 lux, which are recorded by the consumer illumination meter. Figure 7(c) and (d) show the histograms of the luminance of the Fig. 7(a) and (b). The luminance values of the Fig. 7(c) were distributed over 0, while those of the Fig. 7(d) were distributed widely over the range from 0 to 70.

In the Scene #2, Fig. 7(e) and (f) are captured with normal and the final fused image. The final fused image shown in Fig. 7(f) simultaneously captures information of the two gretagmacbeth charts, while the normal exposure can capture only one gretagmacbeth chart of the bright area. There are luminance values of three points, ①: 8.3 lux, ②: 873 lux, which are recorded by the consumer illumination meter. Figure 7(g) and (h) show the histograms of the luminance of the Fig. 7(e) and (f). The most of the luminance values of the Fig. 7(g) were distributed at 0 and 255, while those of the Fig. 7(h) were distributed widely over the range from 0 to 255.

In the Scene #3, Fig. 7(i) and (j) are captured with normal and the final fused image. The final fused image shown in Fig. 7(j) simultaneously captures more information of the outdoor (the stairs of the playground and fine trees) scene than that of the normal exposure. There are luminance values of three points, ①: 16,675 lux, ②: 64.8 lux, ③: 35.8 lux, ④: ∞ lux which are recorded by the consumer illumination meter. Figure 7(k) and (l) show the histograms of the luminance of the Fig. 7(i) and (j). The luminance values of the Fig. 7(k) were distributed at 255, while those of the Fig. 7(l) were distributed widely over the range from 45 to 75. Once again, we see that the proposed method performs very well to achieve more information in the image.

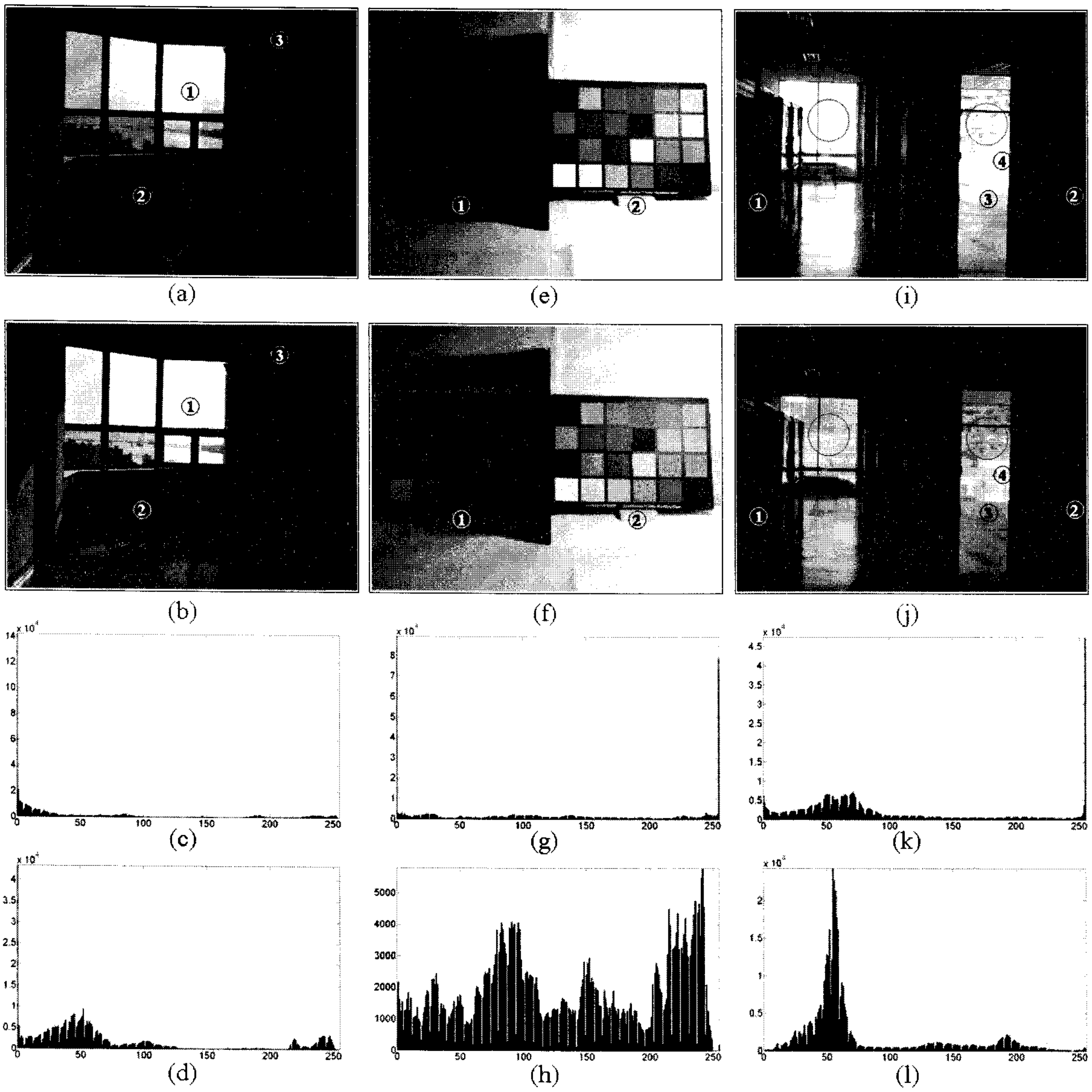

Fig. 7. Experimental results, (a) Scene #1-normal exposure, (b) Scene #1-proposed method, (c) histogram of the luminance of (a), (d) histogram of the luminance of (b), (e) Scene #2-normal exposure, (f) Scene #2-proposed method, (g) histogram of the luminance of (e), (h) histogram of the luminance of (f), (i) Scene #3-normal exposure, (j) Scene #3-proposed method, (k) histogram of the luminance of (i), and (l) histogram of the luminance of (j)

IV. CONCLUSIONS

In conclusion, we propose the dynamic range enhancement of the camera images by using a double-exposure image processing method for mobile phone cameras. In order to improve the dynamic range, we use a double-exposure method and then we apply brightness weight and histogram equalization to the original fused image in inversely proportional to the average luminance values of the sub-regions. In order to verify the performance of the proposed system, we evaluated the images processed by the proposed system and compared them to the AE images, by recording by the illumination meter. The proposed system can be applied to many mobile devices, such as mobile phone cameras, digital still cameras, and so on.

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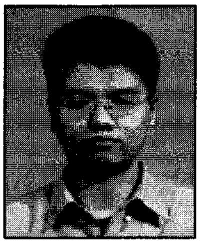

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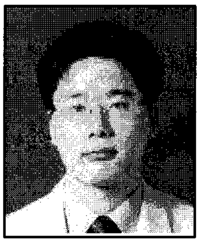

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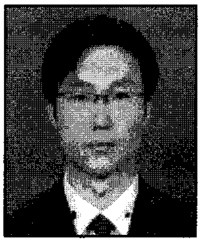

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