Wide Range Dynamic Imaging Techniques with one Time Exposure

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Abstract—The proposed algorithm used an inverting local pattern approach to compensate histogram of the lighting distribution. To improve processing efficiency, the sampling image is classified into three types with various processing methodologies, to achieve a suitable correct factor. The inverting factor is mixed with the original sample, to get dark brightening and bright darkening effect. Then the brightness enhancement and auto-gain-control are post-processed to expand the range of gray level.

Keywords—histogram, pattern, gain control, image processing

I .Introduction

In order to improve the imaging qulaity, high dynamic range (HDR) algorithms are presented in recent. The HDR algorithm is to expand the visible range at a part of the bright and dark scene at the same time for imaging details presented. Multiple exposure methods [1-3] are efficient to expand the dynamic range. Catching three images under three different exposures are used based on the gradient-based synthesis [2]. A set of images involved in the same scene made with different exposures. A HDR pixel is computed by three images according to Gaussian blending function and cutting function to reserve high quality part of each sampling. However, the multiple exposure approach increases computational time. Recently, V. Vonikakis *et al.* [4] proposed a single exposure algorithm to reduce the computational cost. This approach comprises three different stages: a linear stretch, block parameter estimation and contrast modification. This approach can achieve good improvement for HDR images using a short execution time. However, the download- and up- sample may degrade image resolution possible. G. Guarnieri [7] et al. used the techniques of logarithms and exponential-based edge-preserving low-pass and multi-resolution acceleration. Since the iteration operation is used, this is inevitable to increase computation time. K. Kim *et al.* [8] presented a retinex algorithm, which proposed a tone mapping function to improve the dark area contrast. The algorithms [7.8] are not effective for over-exposed regions to reduce positive saturation based on retinex-like approach.

In this study, we present a high performance HDR algorithm using a single image processing to fasten computational speed. Based on LCD backlight theory, an inverted pattern approach is proposed to improve both over- and under- exposed regions at the same frame for a camera imaging system. For real-time application, this algorithm uses one-pass processing flow to keep low computational complexity.

II. Proposed Fast Algorithm for HDR Image Generation

For real-time application, we proposed one-pass processing instead of iterative operation. Figures 1 illustrates a flow chart of the proposed HDR algorithm. First, the original image is converted from the RGB to YCbCr. The luminance signal Y is used to determine the frame type using histogram analysis. The frame type for HDR computing is classified to three types: dark, bright and extreme type. Dark enhancement is applied to dark and extreme type to improve the region of low gray level. On the other path, the inverse pattern y_{inv} is generated from an inverse kernel which includes 2x2 maximum fill, 3x3 low-pass and inverse operation. The inverted patterns y_{inv} are mixed by using the factor of the original luminance signal. The results are further processed by the modules of bright enhancement and AGC (Automatic Gain Control)[11]. Finally, the color HDR image is generated by YCbCr to RGB conversion.
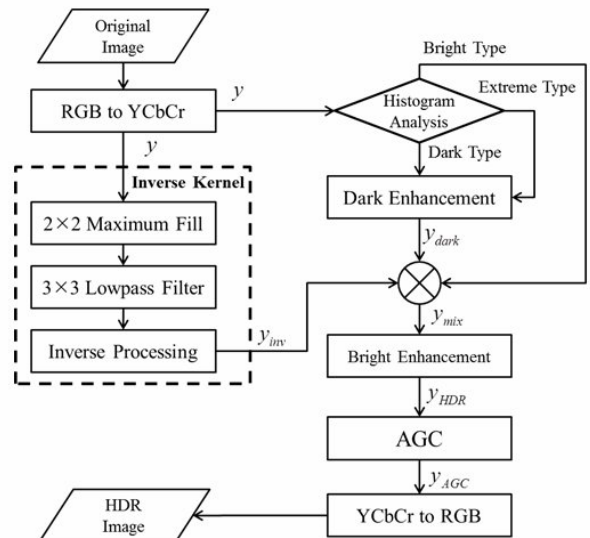

Fig. 1 Block diagram of the proposed HDR algorithm

When the current frame is sampled, we first estimate light distribution using histogram analysis before HDR computing. According to histogram distribution, the frame is classified to three types: (a). Dark Type : most of distribution are in the low-gray level. (b). Bright Type: most of distribution are in the high-gray level. (c). Extreme Type: both of high- and low- gray levels occupied most of distribution.

Table 1 Condition of three types.

Type	Condition
Dark	$Lo > 2Hi$
Bright	$Hi > 2Lo$
Extreme	$\frac{1}{2} \le \frac{Hi}{Lo} \le 2$ and $Hi \ \& \ Lo > \frac{P_{total}}{4}$
Normal	Other conditions

For this, we devise two parameters Hi 及 Lo, for type decision of an 8-bit image, which can be expressed by

$$\begin{cases} Hi = \sum_{i=Th3}^{Th4} h(i) + \sum_{i=Th4}^{255} h(i) \times 2 \\ Lo = \sum_{i=0}^{Th1} h(i) \times 2 + \sum_{i=Th1}^{Th2} h(i) \end{cases} \quad (1).$$

The parameter Hi denotes the accumulation of the number of gray-level between thresholds between Th3 to Th4. To enhance the extra bright feature, we take the double number between Th4 to 255, to accumulate to Hi. Similarly, the parameter Lo represents to accumulate the double number of gray level range from 0 to Th1 and to accumulate the interval with the threshold Th1 to Th2 pixels. If the sampling image is too dark, Lo value will be large. If Hi value is high, the sampling frame is possible to be brightness.

According to the parameters Hi and Lo, the frame type can be efficiently classified, as listed in Table 1. If $Lo > 2Hi$, the sampling frame is too dim, this belongs to dark type. If $Hi > 2Lo$, this is a bright type since the sampling level is high on average. When $\frac{1}{2} \le \frac{Hi}{Lo} \le 2$ and $Hi \ \& \ Lo > \frac{P_{total}}{4}$, where P_{total} is the number of total pixels, this is classified as a extreme type since the sampling pixels included the partial positive and negative saturation at the same frame. If the sampling frame is not satisfied these conditions, this is a normal case ; we do not require any HDR processing.

The inverse kernel consists of three sub-modules that are 2×2 maximum fill, 3×3 low-pass filter and inverse operation. The detailed description for each block is following:

(i). 2×2 maximum fill: is used to keep original detail thin information for HDR algorithm. Four pixels in a 2×2 block is filled by the maximum value of four pixels. First, we search the maximum value of the pixels of 2×2 block. Then, all pixels of 2×2 block are filled by the maximum value. Figure

2(a) shows the original image, and the result of 2×2 maximum fill is shown in Fig. 2(b).
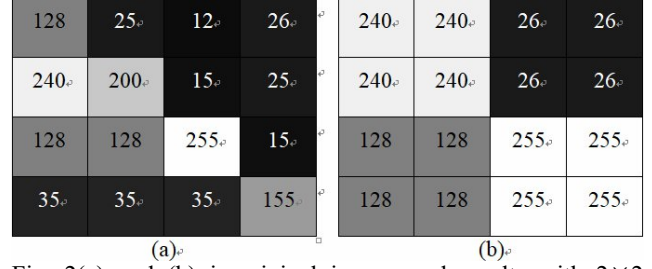

(a)   (b)

Fig. 2(a) and (b) is original image, and results with 2×2 maximum fill

(ii) 3×3 low-pass filter : is used to smooth the pixel after 2×2 maximum filling operation. Because 2×2 maximum fill will make the image to appear jagged edges, low-pass filter is used to smooth jagged edges.

(iii) Inverse operation : achieves inverse function of input pixel in order to enhance the level of dark region and reduce to brightness level to avoid negative and positive saturation. We adopt a square linear function to improve the performance of dark region, which can be given by

$$y_{inv}(i,j) = \frac{\left(255 - y_{lpf}(i,j)\right)^2}{255} \quad (2),$$

for 8-bit image. The inverse function gives the maximum gain for the lowest brightness pixel. The gain gradually decreases when the gray value increases.

First, we compensate the dim region for dark type and extreme type to promote the dark level, the dark pixel is enhanced by

$$y_{dark}(i,j) = \begin{cases} y_{in}(i,j) + (Th_{dark} - y_{in}(i,j)) \times 0.05 & if \quad y_{in}(i,j) < Th_{dark} \\ y_{in}(i,j) & if \quad y_{in}(i,j) \ge Th_{dark} \end{cases} \quad (3)$$

, where the threshold Th_{dark} is defined by

$$Th_{dark} = \begin{cases} 128 & if \quad y_{in} = \quad \text{Dark Type} \\ 50 & if \quad y_{in} = \quad \text{Extreme Type} \\ 0 & if \quad y_{in} = \quad \text{Bright Type} \end{cases} \quad (4)$$

, where y_{in} is an original input Y signal. This operation further adds one minimum value for very low level pixel to avoid negative saturation. If y_{in} is lower, the gray level is improved larger using (6). When the frame type is dark, the gray level is enhanced if it is less than 128. For extreme type, the pixel level is increased only if the gray level is less than 50. We skip the dark enhancement for bright type when setting Th_{dark} =0.

For HDR display, we take a mixing operation of the inverse pixel from (2) and dark enhanced pixel from (3) by

$$y_{mix}(i,j) = y_{dark}(i,j) \times y_{inv}(i,j) \times k \quad (4)$$

, where k is a key parameter to decide HDR image. If k is larger, we obtain stronger degree of HDR. The dark portion is raised because its inverse backlight y_{inv} is high. On the opposite case, the bright pixels can be reduced due to low y_{inv}, which can overcome pixel to be over-exposure. To find a

better k parameter, we select three type pictures for testing, and find a suitable k value for any picture in experiments. When Lo value that is from (1) is high, we require larger k to adjust image brightness. Since high Lo implies more dark pixels in the frame, the k is enlarged to increase the gain of level increment.

After the mixing operation, the luminance of dark region is promoted. However, the bright region is compressed. To expand the dynamic range, the pixel level is further promoted by bright enhancement by

$$y_{HDR}(i,j) = \begin{cases} y_{mix}(i,j) + \left(y_{dark}(i,j) - Th_b\right)^2 \times 0.005 & if \quad y_{dark}(i,j) \geq Th_b \\ y_{mix}(i,j) & if \quad y_{dark}(i,j) < Th_b \end{cases} \tag{5}$$

III. Simulations and Comparisons

To simulate the proposed HDR performance, various image types are sampled for testing. First, we estimate with and without using maximum fill in the inverse kernel. Figure 3(a)-(c) show the original sampling image, and HDR processing without and with 2×2 maximum fill operation. Clearly, the detail "line" and edge will be disappeared when
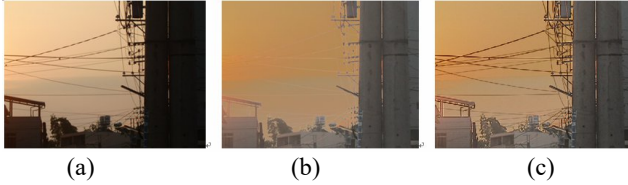

| (a) | (b) | (c) |

Fig. 3(a) is original image, Fig. 6(b) HDR processing without 2×2 maximum fill, Fig. 6(c) HDR processing with 2×2 maximum fill.

HDR processing without using 2×2 maximum fill. Hence 2×2 maximum fill operation is required for our proposed algorithm to keep the detail thin information.

In order to estimate the performance of HDR algorithm by subjective measurement, we defined the parameter HB (histogram balance) as

$$HB = \sum_{i=0}^{255} \left| h(i) - \frac{height \times width}{256} \right| \tag{6}$$

. where the frame size is height x width. Since the image resolution is 8 bits, the gray level is 256. So the average histogram of each level is (height x width)/256. The symbol $h(i)$ is the counting number of the ith level in a histogram.

When each $h(i)$ is close to average histogram, HB becomes smaller. This denotes that the distribution of each gray level is near to uniform, such that the dynamic range of image is wider to achieve better HDR performance.

For comparisons, we select one HDR algorithm based on FCSCM(Fast centre–surround contrast modification,) approach [4] using one time exposure for the single frame processing. This algorithm can solve the problem of under- and over-exposed sampling. The sampling image is processed by FCSCM and the proposed algorithm for objective and subjective evaluations. We select the sampling image with extreme, dark and bright type for testing. Figures 4(a)-(c)

show the extreme type, where many pixels that are near to negative and positive saturation locate on low and high levels at the same frame. The FCSCM [4] can reduce MB value and improve the image quality. Our algorithm can adaptively compute k value to suit for various images for HDR image generation. Results show that our algorithm can achieve lower HB and better image quality than [4]. Next, the dark-type images are tsted, the results are shown in Fig. 5 (a)-(c). For dark type, the k value is adaptively to higher to compensate the dim region efficiently. Finally, we test the bright type. This type may contain positive saturation pixels. According to our algorithm, k is adapted to be small. The high-level pixels of too bright region can be reduced to avoid positive saturation. Results are shown in Fig. 6(a)-(c). Clearly, the positive saturation pixel can be reduced in histogram distribution. From these results, the proposed method indeed improves the image quality in objective view, and better HB value for subjective measurements.

For objective evaluation, Table 2 listed the HB value of all testing images for original ones, and the results of [4] and the proposed method respectively. In average, our HB value can
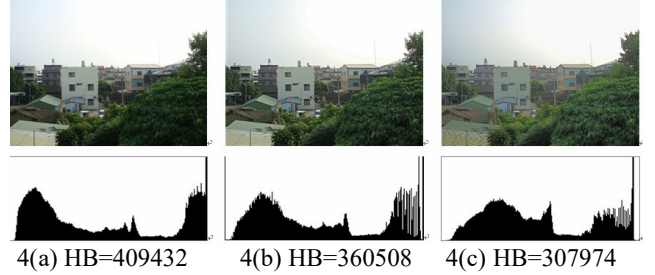

| 4(a) HB=409432 | 4(b) HB=360508 | 4(c) HB=307974 |

Fig. 4 (a)-(c) show the original image, and the result of [4] and the proposed method for extreme type.

| 5(a) HB=479788 | 5 (b) HB=378626 | 5 (c) HB=323734 |
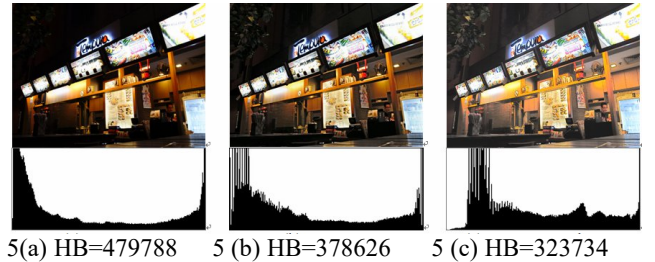
Fig. 5 (a)-(c) show the original image, and the result of [4] and the proposed method for dark type.

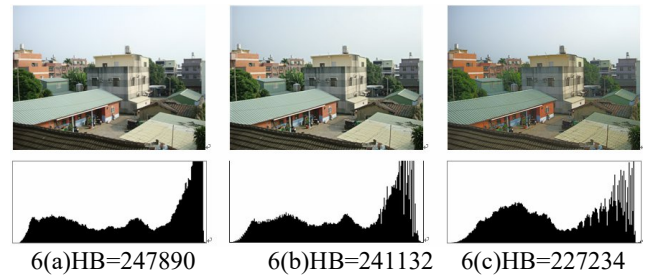| 6(a)HB=247890 | 6(b)HB=241132 | 6(c)HB=227234 |

Fig. 6 (a)-(c) show the original image, and the result of [4] and the proposed method for bright type.

Table 2 Average HB of 8 pictures using difference methods

Images	Type	Original	FCSCM	Proposed
P1	Extreme	384180	343110	317534
P2	Extreme	442248	418368	394906
P3	Extreme	409432	360508	307974
P4	Dark	475654	407864	353938
P5	Dark	398796	343832	309780
P6	Dark	479788	378626	323734
P7	Bright	315822	318028	339708
P8	Bright	247890	241132	227234
Average HB		394226	351434	321851

reduce about 18 % of original image. Compared with the competing algorithm [4], our method can reduce it about 8%. Clearly, the proposed HDR algorithm can achieve better performance in both of objective and subjective test.

IV. Conclusions

In this paper, we present a high-performance HDR algorithm using only one exposure time. Based on LCD backlight principle, the inverse pattern is adaptively generated to according to the imaging dat. Using the frame type classification, the HDR algorithm can adaptively compute the parameter to suit various image features processing. Results shown the proposed algorithm can achieve superior HDR image either under-exposed or over-exposed regions. The resulted HDR images look like natural scene without the effects of halo and art-made. Additional, the algorithm used one-pass processing instead recursive processing, which can save more computational cost. For subjective measurement, we present HB parameter to evaluate the performance of HDR algorithm. The HB value can be improved by 18% and 8% compared with the original image and the result of competing method [4] on average, respectively. With high-performance and low computations, the proposed algorithm can be applied on a real-time camera imaging system.

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