Image enhancement through weighting function estimation with infrared image

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Abstract—**This work presents an efficient image fusion of the visible range (VR) and infrared range (IR) images for image enhancement in digital still camera. Fusion is achieved by estimating the weighting parameters which contain the properties of IR image and by combining the VR and IR images using the parameters. Specifically, the weighting parameters are calculated from the estimated illumination and detail components by a weighted low pass filter (WLPF). In addition, for a user preference, we compress dynamic range of the fused image using a retinex technique and adjust contrast/color based on global color distribution. Experiment results show that the proposed scheme produces good outcomes in terms of visual observation and numerical score.**

***Keywords-** image fusion, infrared image, and detail enhancement.*

I. INTRODUCTION

Infrared image has a lot of helpful information being able to enhance a visible range (VR) image such as a wavelength property. Recently, in order to enhance the image quality of a digital camera, many approaches have been tried to use these information. Image fusion-based enhancement is mainly classified into two types: spatial; and frequency domain processing. Representative approaches in the spatial domain processing are using averaging like Brovey method, pricipal component analysis (PCA), and intensity-hue-saturation (IHS) distribution. Additionally, high pass filtering-based approaches belong to this category as well. IHS method generates a high spectral image by controlling the intensity of an inputted image based on higher resolution image. This technique reported a good result in preserving topography and texture [1, 2]. Another efficient fusion method is based on PCA [3].

A representative fusion method in the frequency domain is based on Wavelet transform [4-7]. It employs a pyramid structure for decomposing and reconstructing the given image and produces a better result than IHS and PCA-based approaches in preserving original useful information. However, it has shortcomings of high complexity and long processing time and it is very sensitive to the accuracy of registration. Besides wavelet transform, there are Laplacian pyramid and Curvelet transform-based algorithms.

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In this paper, we propose an efficient fusion method in spatial domain using WLPF and properties of an infrared range (IR) image from the compact digital camera.

II. PROPOSED ALGORITHM

A. Fusion of VR and IR images

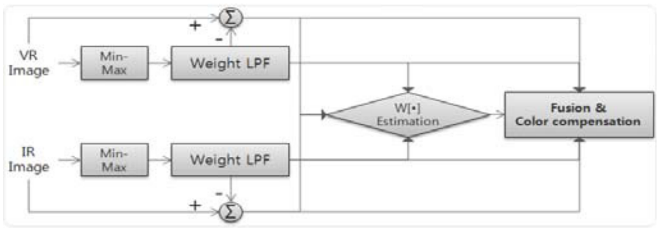

Fig. 1. Fusion block diagram

Fusing the VR and IR images is generated by properly mixing the illumination and detail components of each image. For this purpose, we first decompose an image into the illumination and detail components using a weighted low pass filter (WLPF) [10] as shown in Fig. 1. WLPF minimizes halo artifacts around large edges since it has a property of preserving large edges and blurring small details. The filtered images $\tilde{I}_{VR}(i)$ and $\tilde{I}_{IR}(i)$ are used to estimate a weighting function $W[\cdot]$, and the weighting function plays a main role in enhancing the illumination and detail. Particularly, it is used to fuse the illumination and detail components in the final step. A weighting function $W_{ill}[\cdot]$ for illumination is calculated by

$$W_{ill}(i) = \begin{cases} W_{ill}^{1}(i), & \text{if } \tilde{I}_{VR}(i) < \tilde{I}_{IR}(i) \\ W_{ill}^{2}(i), & \text{else if } V_{VR}(i)/V_{IR}(i) < \tau_h \\ 0, & \text{otherwise} \end{cases} . \tag{1}$$

Where, $W_x(i) = I_x(i) - \tilde{I}_x(i)$ and τ_h is denote the detail component of an image x and is a threshold, respectively. A weighting function $W_{ill}^{1}(i)$ modifies a given pixel value when meeting the condition $\tilde{I}_{VR}(i) < \tilde{I}_{IR}(i)$ pixels. It can restore the disappeared information and enhance the dark region seamlessly. Similarly, another weighting function $W_{ill}^{2}(i)$ is employed for improving the pixels with much brighter pixel values in a VR image than those in an IR image. With this operation, even if the haze and water regions are too weak to

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see in a VR image, these regions are visually well distinguished in IR image and enhanced accordingly. That is, this affects in pixels which rarely ever change in a VR image such as haze regions (please, see Fig. 5 for details). The above two functions for illumination enhancement are calculated by

$$W_{ill}^{1}(i) = \gamma_0 \times \left[\left(\tilde{I}_{VR}(i) \middle/ Max_1 \right) + \left(\frac{1}{\gamma_0} - 1 \right)\right], \quad (2)$$

$$W_{ill}^{2}(i) = \gamma_0 \times \left[\left(\tilde{I}_{VR}(i) \times (1-\gamma_h) \middle/ Max_2 \right) + \gamma_h \left(\frac{1}{\gamma_0} - 1 \right)\right]. \quad (3)$$

Here, γ_0, and γ_h are fusion ratios at each region, Max_1 and Max_2 are maximum values for $\tilde{I}_{VR}(i)$ in $\tilde{I}_{VR}(i) < \tilde{I}_{IR}(i)$, and $I_{VR}(i)$ in $\tilde{I}_{IR}(i) < \tilde{I}_{VR}(i)$, and $V_{VR}(i)/V_{IR}(i) < \tau_h$., respectively. In contrast, the details in a VR image are modified by the following weighting function $W_{var}[\cdot]$ as

$$W_{\mathrm{var}}(i) = \frac{1}{\gamma_{\mathrm{var}}} \times \left(\left(V_{VR}(i) \middle/ \max(V_{IR}(i)) \right) + (\gamma_{\mathrm{var}} - 1) \right), \quad (4)$$
$$\gamma_{\mathrm{var}} = (T - \tau_{\mathrm{var}}) \times \frac{\max(V_{IR}(i))}{\max(V_{VR}(i))}$$

where, γ_{var} denote a fusion ratio of detail components with a maximum amplification T and a value τ_{var}. After the weighting function estimation, a VR image is enhanced by composing the illumination (m_f) and detail (v_f) components as

$$I_f(i) = m_f(i) + v_f(i),$$
$$\begin{cases} m_f(i) = W_{ill}(i) \cdot \tilde{I}_{VR}(i) + (1 - W_{ill}(i)) \cdot \tilde{I}_{IR}(i) \\ v_f(i) = W_{\mathrm{var}}(i) \cdot V_{VR}(i) + (1 - W_{\mathrm{var}}(i)) \cdot V_{IR}(i) \end{cases} \cdot \quad (5)$$

Note that the detail components are fused only in the region of $V_{VR}(i)<V_{IR}(i)$. In other words, the small details in a VR image are enhanced according to those in an IR image.

However, the contrast of the fused image may be reduced by the brightness improvement of dark region and the enhancement of local details. Therefore, we just employ a simple contrast correction[11] for enhancing the image contrast.

III. EXPERIMENT RESULTS

In order to evaluate the performance of the proposed scheme, various test sets of VR and IR images obtained from an identical camera are used for experiments as shown in Fig. 2. Fig. 3 - Fig. 5 show the comparative results of the proposed algorithm.

Fig. 2. The VR(top) and IR(bottom) images

In Fig. 3, the result of the proposed algorithm is compared with the result of a dynamic range compression. It is easily seen that the proposed outputs (the third figures from the left) can restore the disappeared information and enhance details significantly. Additionally, the partial enlarged images are shown in Fig. 4 and Fig. 5 for another test images. Again, we can see that the proposed scheme can significantly enhance the details of dark region as well as haze region.

TABLE I. THE USER PREPERENCE REULST

Rank	Model	Detail	Tone	Color	Analysis
1	Our method	5.15	5.094	5.1	5.114
2	Can**	4.597	4.507	4.368	4.491
3	Sam** NX10	4.442	4.468	4.467	4.472
4	So** W290	4.274	4.481	4.465	4.41
5	Can** 500D	4.22	4.471	4.282	4.385
6	Pana**** FX65	4.188	4.231	4.278	4.257

In this paper, in order to numerically evaluate performance, we performed a subject test for user preference against several camera models using [12], and table I shows its result. The test is carried out in a survey, in which the 73 applicants are participated and the proportion of males to females is 0.46. The preference index was calculated by averaging the results of test images and our method ranked the second to none on the subjective image evaluation.

IV. CONCLUSION

We proposed a scheme that can efficiently fuse the VR and IR images for image enhancement. In this paper, in order to systematically combine them, we calculated the illumination and detail components using WLPF and estimated the weighting functions for mixing the components. Additionally, we also simply employed contrast/color correction algorithm for a user preference of a digital camera. Experimental and subjective tests show that the proposed approach gave visually good results and numerically high user preference. Therefore, we believe that the proposed algorithm can be used as a useful tool for image enhancement in the digital camera-related field.

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Fig. 3. Effect of fusion (left : original, center: the detail enhanced result from original VR image, right: the detail enhanced result from the fused VR+IR image)

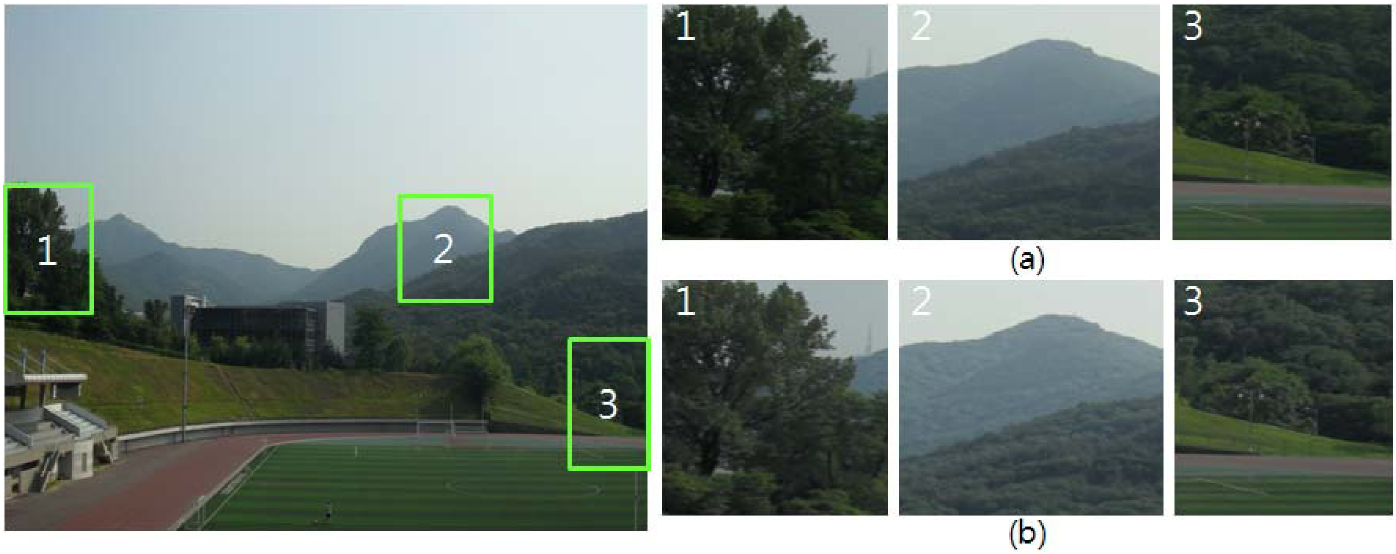

Fig. 4. The partial Results : (a) input, (b) output.

Fig. 5. The partial Results : (a) input, (b) output

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