Image Fusion Based on Grey Polynomial Interpolation

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Abstract

In this paper, an image fusion approach based on grey polynomial interpolation (GPI) is presented to enhance the visual quality for a high contrast image. The objective of image fusion is to integrate different source images and to produce an image with higher visual quality than the source images. In this paper, two source images are obtained by a camera with different exposure parameters. One is of high exposure and the other low. With the GPI, two source images are fused. The results for the given examples indicate that the proposed approach has achieved the goal and is of better visual quality when compared with the scheme in [1].

Index Terms: image fusion, grey system, grey polynomial interpolation

1. Introduction

Nowadays, CCD sensors have been extensively applied to capture an image in many scenarios such as digital camera and surveillance systems. In general cases, the sensors work well in automatic exposure (AE) mode. However, CCD sensors may fail to appropriately present captured pixels when they are saturated to the maximum or minimum values. One example is that an image is taken in a high contrast situation. Though the automatic exposure control is try to determine an appropriate exposure value, the captured image still suffers from missing details in overexposed and underexposed areas. To deal with the cases when automatic exposure mode is not suitable, an image fusion scheme is sought. Since a satisfactory image cannot be obtained in one shot, two images are used in image fusion generally. The objective of image fusion is to integrate source images into an image with higher visual quality than original ones.

Several image fusion approaches have been reported recently. To deal with the focus problem in a multi-object image, wavelet-based image fusion methods were presented to fuse image with different focuses in [1, 2] whose objects in fused images were all clear. In [3], an image fusion scheme to relieve the problem of overexposure and underexposure was presented based on wavelet-based contourlet transform. In [4], a real-time image fusion approach was proposed to solve exposure problem in an image with high dynamic range, where medians of source images were skillfully manipulated.

For schemes in [1-4] and others, image fusion generally requires a mechanism to determine how the information is fused. In this paper, an image fusion approach is proposed from the viewpoint of interpolation where no mechanism is needed to determine the way to fuse source information in available images.

This paper is organized as follows: Section 2 reviews the real-time image fusion (RTIF) method since it is of similar concept to the proposed approach but with different fusion process. Thus, the RTIF scheme is to be compared with the proposed approach in the simulation. Section 3 gives a brief review of one-dimensional grey polynomial interpolation (1-D GPI) which will be applied to fuse source images. Section 4 presents the proposed fusion approach based on GPI. The approach is called image fusion by GPI (IFGPI). Section 5 gives two examples to verify the proposed IFGPI whose results are compared with the ones obtained in the RTIF. Finally, conclusion is made in Section 6.

2. Review of RTIF

In this section, the real-time image fusion proposed in [4] is briefly reviewed. Denote the exposure in automatic mode for a given camera as E. Let an image taken with $2E$ be $\boldsymbol{F}_D$ and with $0.5E$ $\boldsymbol{F}_H$, respectively. Assume that both source images are in YC_bC_r format. Denote the medians of $\boldsymbol{Y}_D$ and $\boldsymbol{Y}_H$ as M_D and M_H, respectively. The maximum value in images $\boldsymbol{Y}_D$ and $\boldsymbol{Y}_H$ is denoted as Φ. Then the implementation steps for the RTIF is described as follows.

Step 1. Obtain the median values M_D, M_H, and the maximum value Φ in $\boldsymbol{Y}_D$ and $\boldsymbol{Y}_H$.

Step 2. Calculate S_D, S_H, and M_D as

$$S_D = M_F / M_D \quad (1)$$

$$S_H = (\Phi - M_F)/(\Phi - M_H) \quad (2)$$

$$M_F = (M_D + M_H)/2 \quad (3)$$

Step 3. Find pixels of fused image in Y component as

$$Y_F(i,j) = \begin{cases} M_F + (Y_H(i,j) + M_H)/S_H & \text{if case 1} \\ Y_D(i,j)S_D & \text{if case 2} \\ (Y_H(i,j) + Y_D(i,j))/2 & \text{else} \end{cases} \quad (4)$$

where case 1 is $Y_H(i,j) > M_H$ and $Y_D(i,j) > M_D$. Case 2 is $Y_H(i,j) < M_H$ and $Y_D(i,j) < M_D$.

Step 4. Find pixels of fused image in Cb component as

$$Cb_F(i,j) = \begin{cases} Cb_H(i,j) \times Y_F(i,j)/Y_H(i,j) & \text{if case 1} \\ Cb_D(i,j) \times S_D & \text{else} \end{cases} \quad (5)$$

Step 5. Find pixels of fused image in Cr component as

$$Cr_F(i,j) = \begin{cases} Cr_H(i,j) \times Y_F(i,j)/Y_H(i,j) & \text{if case 1} \\ Cr_D(i,j) \times S_D & \text{else} \end{cases} \quad (6)$$

Step 6. Continue step 3 to step 5 until all pixels of fused image are found.

3. Review of 1-D GPI

In this section, the one-dimensional grey polynomial interpolation (1-D GPI) is briefly reviewed. For details, one may consult [5]. Since the interpolation performance of GPI is far better than its corresponding PI, thus it is employed in the proposed image fusion approach. Here, only the first-order GPI is reviewed since it will be used in the proposed image fusion approach in Section 4. Given two pixels $\{x(k), \text{for } 1 \le k \le 2\}$, the first-order GPI is described as follows.

Step1. Preprocess $x(k)$ by the first-order accumulated generating operation (1-AGO) as

$$x^{(1)}(k) = \sum_{i=1}^{k} x(i) \quad (7)$$

Step2. Assume $x(k)$ has the following form

$$x(k) = c_1 k + c_0 \quad (8)$$

Step3. Substitue $1 \le k \le 2$ into (8) and find coefficients c_1 and c_2.

Step4. With c_1 and c_2 and by the inverse of 1-AGO, obtain the interpolated pixel $\hat{x}(k+1/2)$ as

$$\hat{x}(k+1/2) = [\hat{x}^{(1)}(k+1/2) - \hat{x}^{(1)}(k)] \times 2 \quad (9)$$

Step5. By an α filter, the final interpolated pixel value is obtained as

$$\hat{x}(k+1/2) = \alpha\hat{x}(k) + (1-\alpha)\hat{x}(k+1/2) \quad (10)$$

where $0 \le \alpha \le 1$.

4. Image Fusion by GPI

In this section, the proposed image fusion approach based on GPI, called IFGPI, is introduced. In the proposed approach, we consider image fusion as an interpolation problem where two pixels, one pixel from one source image and the other form another, are fused to find a corresponding pixel in the fused image. Figure 1 shows the idea just described where $\boldsymbol{F}_{dark}$ and $\boldsymbol{F}_{light}$ denote source images with high exposure and low exposure, respectively. $\boldsymbol{F}_{fused}$ stands for the fused image. Assume source images are of RGB format. With source images $\boldsymbol{F}_{dark}$ and $\boldsymbol{F}_{light}$, the implementation steps of the IFGPI, for R-, G-, and B-components, are given as follows.

Step1. Fetch a two-pixel pair from source images, $\boldsymbol{x} = \{F_{dark}(i,j),\ F_{light}(i,j)\}$ where $F_{dark}(i,j)$ and $F_{light}(i,j)$ denote the (i,j) pixel in $\boldsymbol{F}_{dark}$ and $\boldsymbol{F}_{light}$, respectively.

Step2. By the GPI described in Section 3, the fused pixel $F_{fused}(i,j)$ is found.

Step3. On a pixel-by-pixel basis, continue Steps 1 and 2 until all fused pixels $F_{fused}(i,j)$ are found.

Note that there is no mechanism to determine how to fuse the source images as in [1-4] and other schemes. In the IFGPI, we apply the GPI to all two-pixel pairs in source images without any difference.

5. Simulation Results

In the simulation, two high contrast cases are provided to justify the proposed IFGPI whose results are compared with those from the RTIF. In the simulation, the parameter $\alpha = 0.4$ is used in GPI. For the first case, source images $\boldsymbol{F}_{dark}$ and $\boldsymbol{F}_{light}$ are taken on some street at night which are shown in Figures 2 and 3, respectively. In Figure 2, the image is underexposed and therefore lots of areas cannot be seen. On the other hand, the image in Figure 3 is overexposed. Though the darker areas can be seen, however the brighter parts are saturated and no detail can be seen. The fused images obtained from the RTIF and the IFGPI are given in Figures 4 and 5, respectively. Both approaches are able to improve the image quality. However, the fused image from the IFGPI is better than that from the RTIF since it is clearer and of more natural color.

For the second case, outdoor building images are taken from indoor through a window. Those source images are given in Figures 6 and 7. Figure 8 shows the image with AE mode. It indicates the difficulty to capture both darker and brighter parts clearly. Once one is obtained, another is lost. The fused images for the RTIF and IFGPI are shown in Figures 9 and 10. Again, the one from the IFGPI has better visual quality than that for the RTIF. To sum up, the simulation results indicate that the proposed IFGPI outperforms the RTIF in the given examples.

6. Conclusion

In this paper, an image fusion approach based on the viewpoint of interpolation is presented where no mechanism is required to determine the way to fuse source images. Based on the 1-D GPI, the image fusion approach is developed and is called the IFGPI. Then the IFGPI is applied to deal with the problem of images with high contrast which automatic exposure mode cannot work appropriately. Two examples are provided to justify the proposed IFGPI. The simulation results show that the IFGPI is able to fuse source images appropriately and therefore better visual quality is obtained in the fused image. Moreover, the fused image of the IFGPI has been showed having better visual quality than that for the RTIF, since a clearer image with more natural color is achieved.

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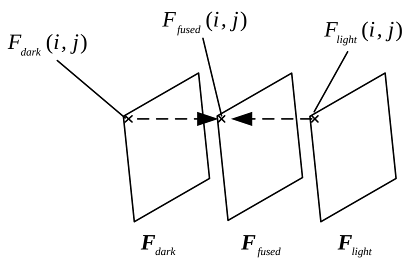

Fig. 1 The interpolation concept in the IFGPI

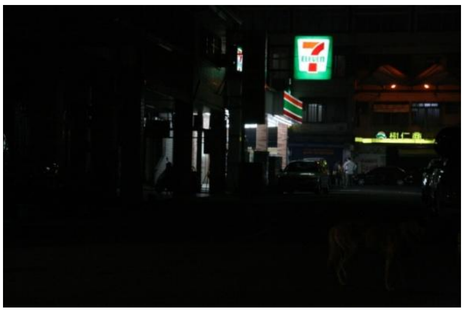

Fig. 2 Source image $\boldsymbol{F}_{dark}$ (7-11)

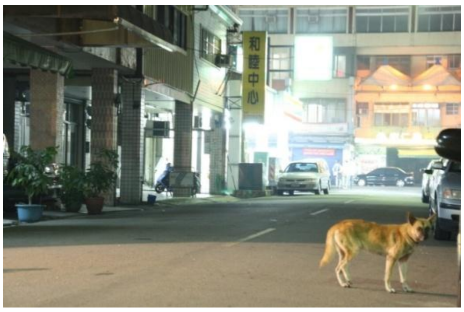

Fig. 3 Source image $\boldsymbol{F}_{light}$ (7-11)

Fig. 4 Fused image by the RTIF (7-11)

Fig. 5 Fused image by the IFGPI (7-11)

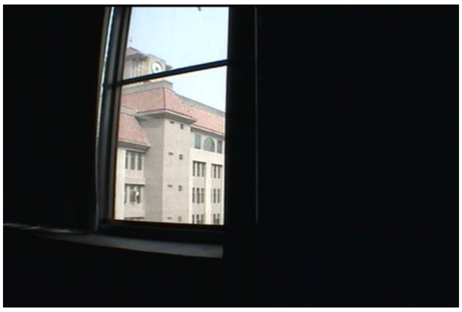

Fig. 6 Source image $\boldsymbol{F}_{dark}$ (Building)

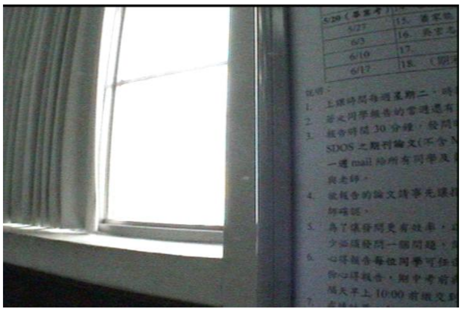

Fig. 7 Source image $\boldsymbol{F}_{light}$ (Building)

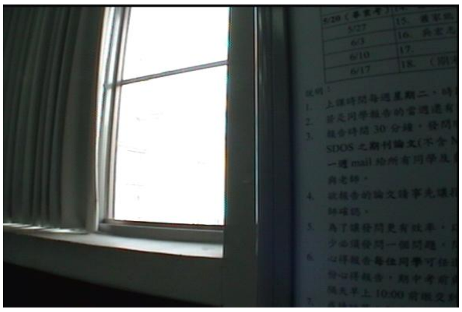

Fig. 8 Image with AE mode (Building)

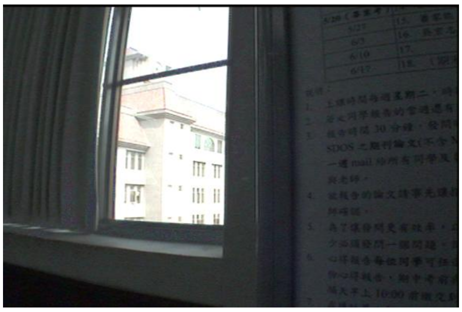

Fig. 9 Fused image by the RTIF (Building)

Fig. 10 Fused image by the IFGPI (Building)