Filter Size and Color Pattern Investigation for Yamanaka Patterned Color Filter Array

Gwanggil Jeon

Department of Embedded Systems Engineering, Incheon National University
12-1 Songdo-dong, Yeonsu-gu, Incheon 406-772, Korea
gjeon@incheon.ac.kr

Abstract

The digital cameras utilize a CFA to take the colors of the scene. The downsampled versions of the red, green, and blue parts are obtained, and an upsampling of those three colors is needed to restore a full representation of the CFA image. In this paper, we study on Yamanaka patterned CFA. We conducted experiments in various scenarios with different size of filters and RGB patterns such as RRGB, RGGB, and RGBB.

Keywords: *Yamanaka pattern, downsampling, upsampling, color filter array, various pattern*

1. Introduction

In digital cameras, colors of the scene are acquired by a single CCD sensor array due to price issue. Thus each pixel for the sensors only discovers one color determined by color filter array (CFA) [1, 2]. The most widely used CFA is Bayer pattern, and it places twice more green information on a quincunx grid, and the rest colors (red and blue) at rectangular grid [3]. However, there are few other patterns proposed by many researchers. In this paper, we study on Yamanaka patterned CFA. Due to lost color information by downsampling process, the upsampling stage is necessary to restore a full color representation of the image. Normally this process is called color interpolation or demosaicking. The main purpose of this process is to avoid zippering and aliasing [4, 5].

In literature, there have been many color restoration approaches proposed [6-27]. Earlier methods were mostly based on simple approaches such as nearest-neighbor methods, bilinear interpolation and bicubic spline interpolation methods. However, there did not give satisfactory results in both of objectively and subjectively. Later, the better results were attained by the methods that adventure the inter-color-channel relationship where red and blue interpolation were supported by the information of green channel. Recently newer methods were presented which are based on edge-directed interpolation, where the color information restoration is achieved in the direction of obtained edges, thus the demosaicking is performed along the detected edges.

In this paper, we propose a new color interpolation method based on different color patterns and filter size. Section 2 describes the proposed CFA patterns and filter size configuration. The performance of the proposed approach are examined and discussed in Section 3 and finally, in Section 4, we report the conclusions.

2. Transition to Yamanaka patterns from Bayer patterns

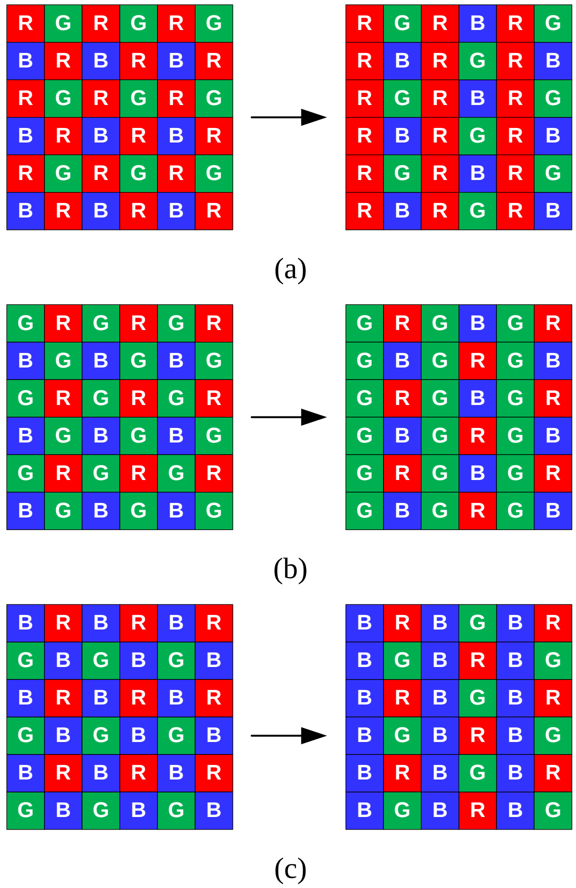


Figure 1. Bayer and Yamanaka patterns used in single-CCD digital cameras: (a) RRGB, (b) RGGB, and (c) RGBB

The Yamanaka CFA pattern was firstly reported in 1977. For RGGB case, the matrix to make Bayer pattern (Eq. (1)) and Yamanaka CFA pattern (Eq. (2)) are,

$$\begin{bmatrix} G & R & G & R \\ B & G & B & G \\ G & R & G & R \\ B & G & B & G \end{bmatrix}, \quad (1)$$

$$\begin{bmatrix} G & R & G & B \\ G & B & G & R \\ G & R & G & B \\ G & B & G & R \end{bmatrix}. \quad (2)$$

Figure 2 shows the flowchart to obtain Yamanaka patterned CFA from the original image.

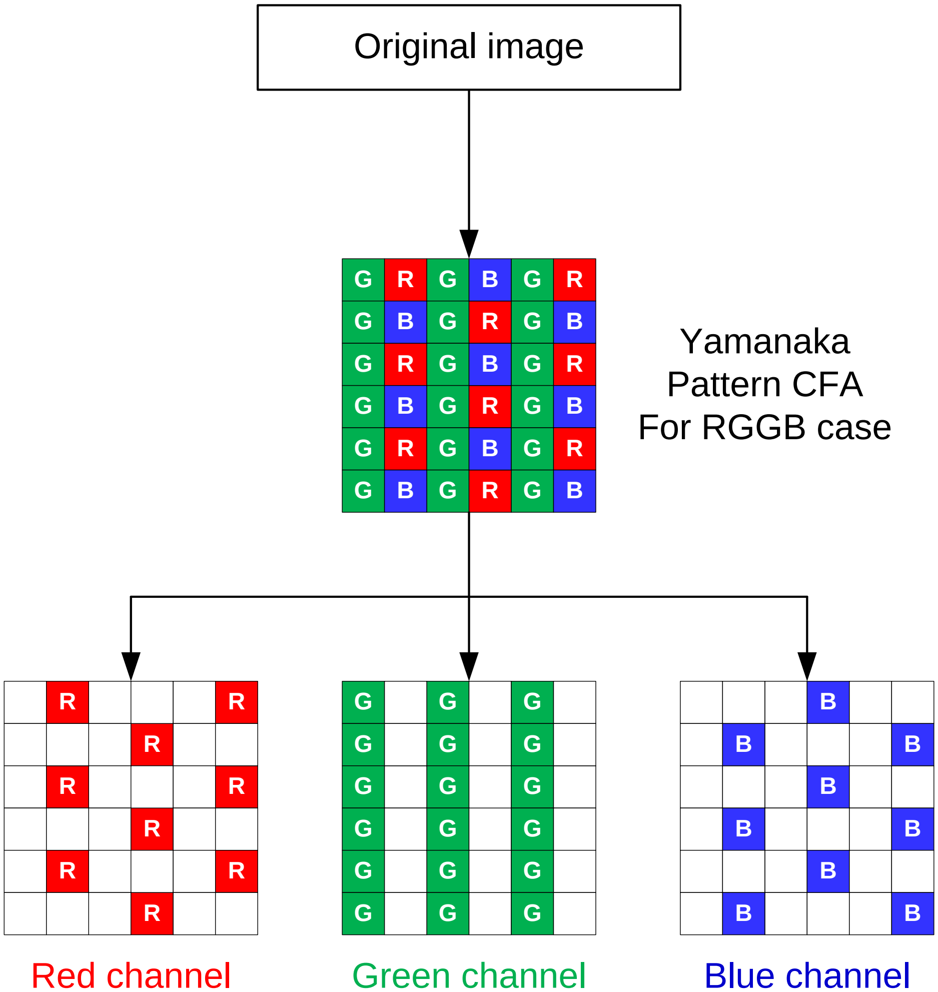
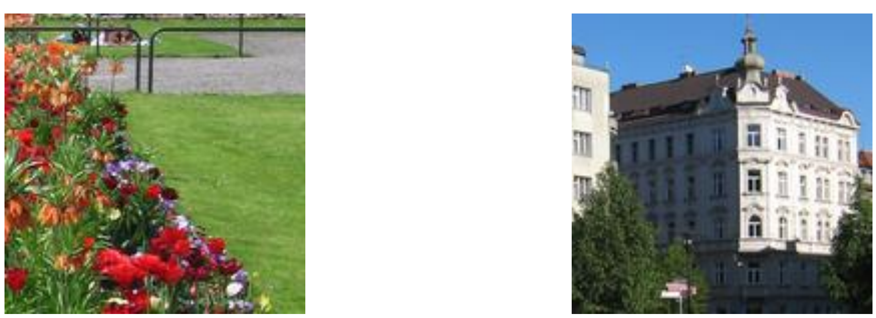


Figure 2. Flowchart to obtain Yamanaka patterned color channel from original image

Figure 3 shows the RRGB, RGGB, and RGBB patterned CFA images, respectively.



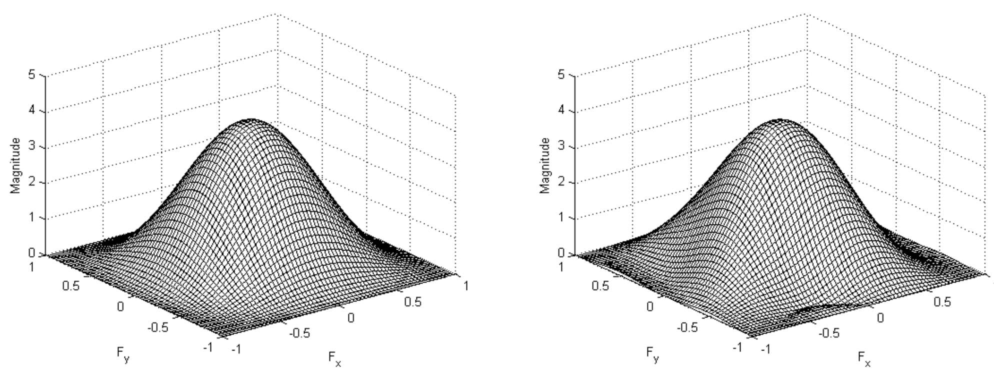
(a)

(b) (c) (d)

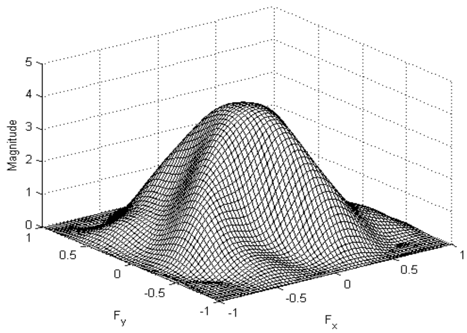
Figure 3. (a) Original LC #9 and #10 images. Yamanaka CFA's (b) red channel, (c) green channel, and (d) blue channel

3. Least Squares Methods for Yamanaka CFA

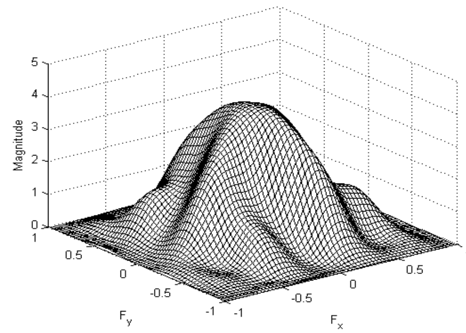
We used least-squares method [28] to create filters. We set several scenarios such as filter size configuration and color pattern configuration. The obtained filters' frequency responses and coefficients are shown in Figures 4 and 5.



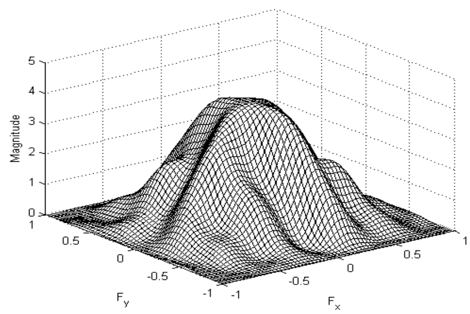
(a) (b)



(c)



(d)



(e)

Figure 4. Frequency response of obtained filters for green channel, under the condition of RGBB pattern with the filter size of (a) 3×3, (b) 5×5, (c) 7×7, (d) 9×9, and (e) 11×11

0.2760	0.5024	0.2333
0.5092	1.0000	0.4906
0.2364	0.4984	0.2555

(a)

0.0000	-0.0274	-0.0000	0.0533	0.0000
0.0615	0.2760	0.4973	0.2333	-0.0534
-0.0000	0.4829	1.0000	0.4688	0.0000
-0.0584	0.2364	0.4970	0.2555	0.0569
-0.0000	0.0567	0.0000	-0.0337	-0.0000

(b)

-0.0328	-0.0315	-0.0389	-0.0117	0.0542	0.0021	-0.0266
-0.0032	0.0000	-0.0198	-0.0000	0.0663	-0.0000	-0.0297
0.0841	0.0818	0.2831	0.5082	0.2246	-0.0443	-0.0386
0.0129	-0.0000	0.4779	1.0000	0.4638	0.0000	0.0154
-0.0420	-0.0508	0.2235	0.5077	0.2659	0.0741	0.0753
-0.0199	-0.0000	0.0649	0.0000	-0.0285	0.0000	0.0002
-0.0236	0.0043	0.0611	-0.0129	-0.0454	-0.0272	-0.0238

(c)

0.0000	0.0006	0.0000	-0.0173	0.0000	0.0410	-0.0000	-0.0229	-0.0000
-0.0368	-0.0328	-0.0177	-0.0389	-0.0062	0.0542	0.0058	-0.0266	-0.0023
0.0000	-0.0020	-0.0000	-0.0130	-0.0000	0.0452	0.0000	-0.0181	-0.0000
0.0764	0.0841	0.0554	0.2831	0.5022	0.2246	-0.0368	-0.0386	-0.0337
-0.0000	0.0152	0.0000	0.4753	1.0000	0.4621	-0.0000	0.0179	0.0000
-0.0362	-0.0420	-0.0430	0.2235	0.5022	0.2659	0.0487	0.0753	0.0699
0.0000	-0.0079	-0.0000	0.0409	0.0000	-0.0169	-0.0000	0.0013	-0.0000
-0.0030	-0.0236	0.0086	0.0611	-0.0080	-0.0454	-0.0157	-0.0238	-0.0298
-0.0000	-0.0247	0.0000	0.0488	-0.0000	-0.0264	0.0000	0.0013	-0.0000

(d)

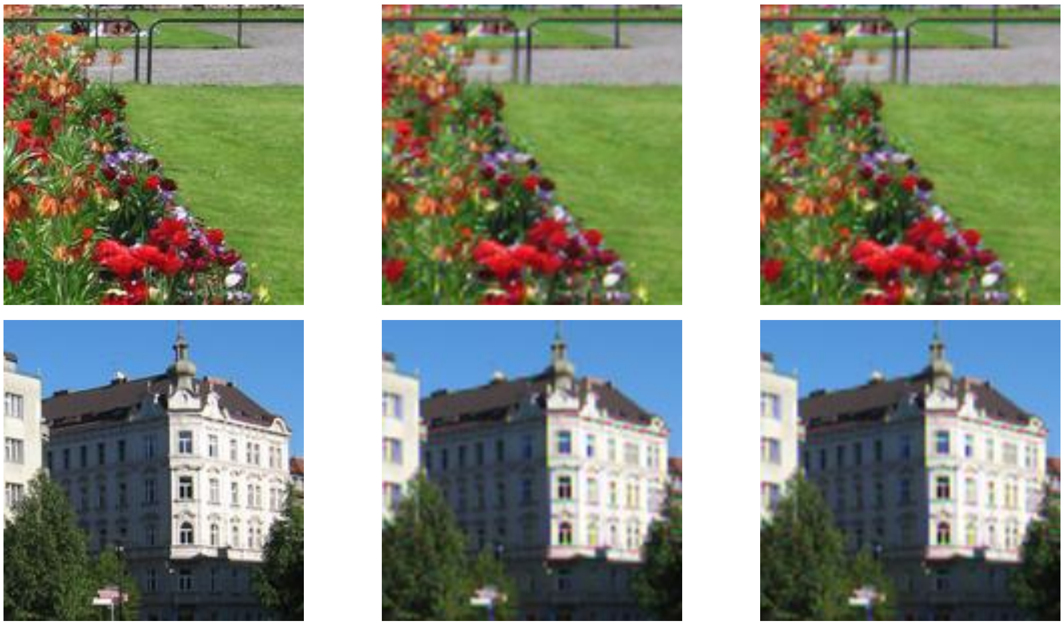
-0.0016	-0.0020	-0.0014	-0.0080	-0.0204	-0.0006	0.0336	0.0076	-0.0091	0.0039	0.0048
-0.0050	0.0000	0.0033	-0.0000	-0.0165	0.0000	0.0417	-0.0000	-0.0210	-0.0000	-0.0025
-0.0351	-0.0351	-0.0162	-0.0132	-0.0239	-0.0058	0.0395	0.0018	-0.0181	-0.0047	-0.0084
0.0073	-0.0000	-0.0034	0.0000	-0.0139	-0.0000	0.0458	-0.0000	-0.0160	0.0000	-0.0051
0.0633	0.0765	0.0636	0.0555	0.2735	0.5015	0.2243	-0.0372	-0.0305	-0.0338	-0.0283
0.0019	-0.0000	0.0142	-0.0000	0.4745	1.0000	0.4616	0.0000	0.0175	0.0000	-0.0003
-0.0230	-0.0363	-0.0360	-0.0435	0.2221	0.5015	0.2559	0.0488	0.0542	0.0700	0.0629
-0.0073	0.0000	-0.0051	-0.0000	0.0418	0.0000	-0.0177	0.0000	-0.0000	-0.0000	0.0071
-0.0131	-0.0039	-0.0095	0.0036	0.0431	-0.0087	-0.0314	-0.0104	-0.0062	-0.0274	-0.0294
-0.0036	-0.0000	-0.0220	0.0000	0.0497	-0.0000	-0.0253	-0.0000	0.0051	-0.0000	-0.0067
0.0030	0.0011	-0.0151	0.0099	0.0435	0.0017	-0.0189	-0.0098	-0.0037	-0.0032	-0.0077

(e)

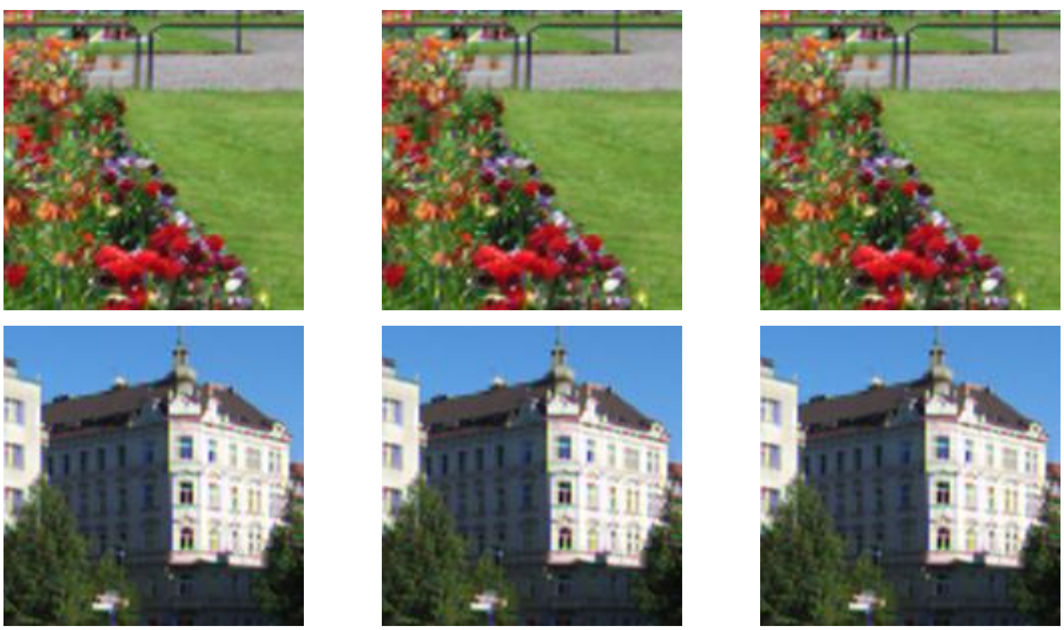
Figure 5. Coefficients of obtained filters for green channel, under the condition of RGBB pattern with the filter size of (a) 3×3, (b) 5×5, (c) 7×7, (d) 9×9, and (e) 11×11

4. Simulation results

In this paper, we used two performance metrics, CPSNR and SCIELAB [29]. We used ten natural images with the size of 720×540 (or 540×720), which are downloadable here [30]. The original dataset contains 150 images, and we only used first 10 images. Figures 6-8 shows the results images for RGBB, RGGB, and RGBB cases.

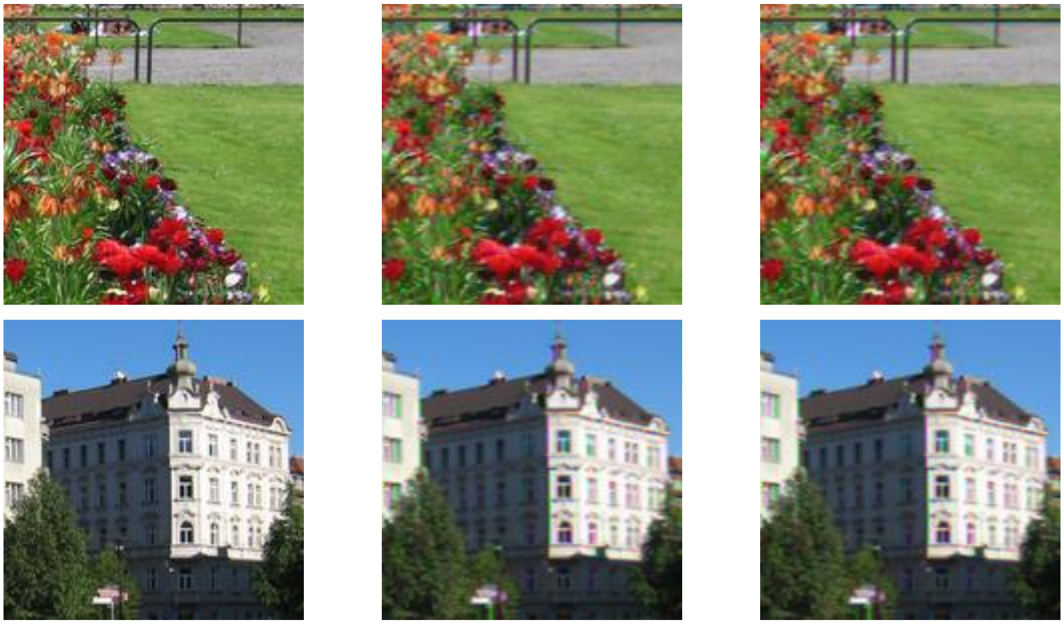


(a) (b) (c)

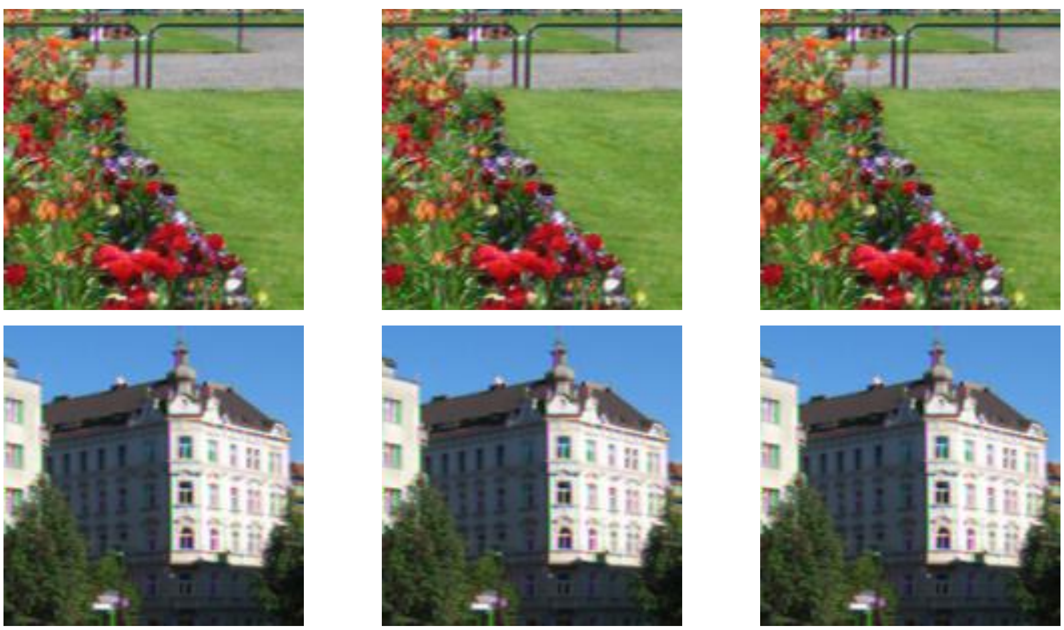


(d) (e) (f)

Figure 6. Reconstructed images of RRGB patterned #9 and #10 images. (a) Original images, (b) 3×3, (c) 5×5, (d) 7×7, (e) 9×9, and (f) 11×11



(a) (b) (c)

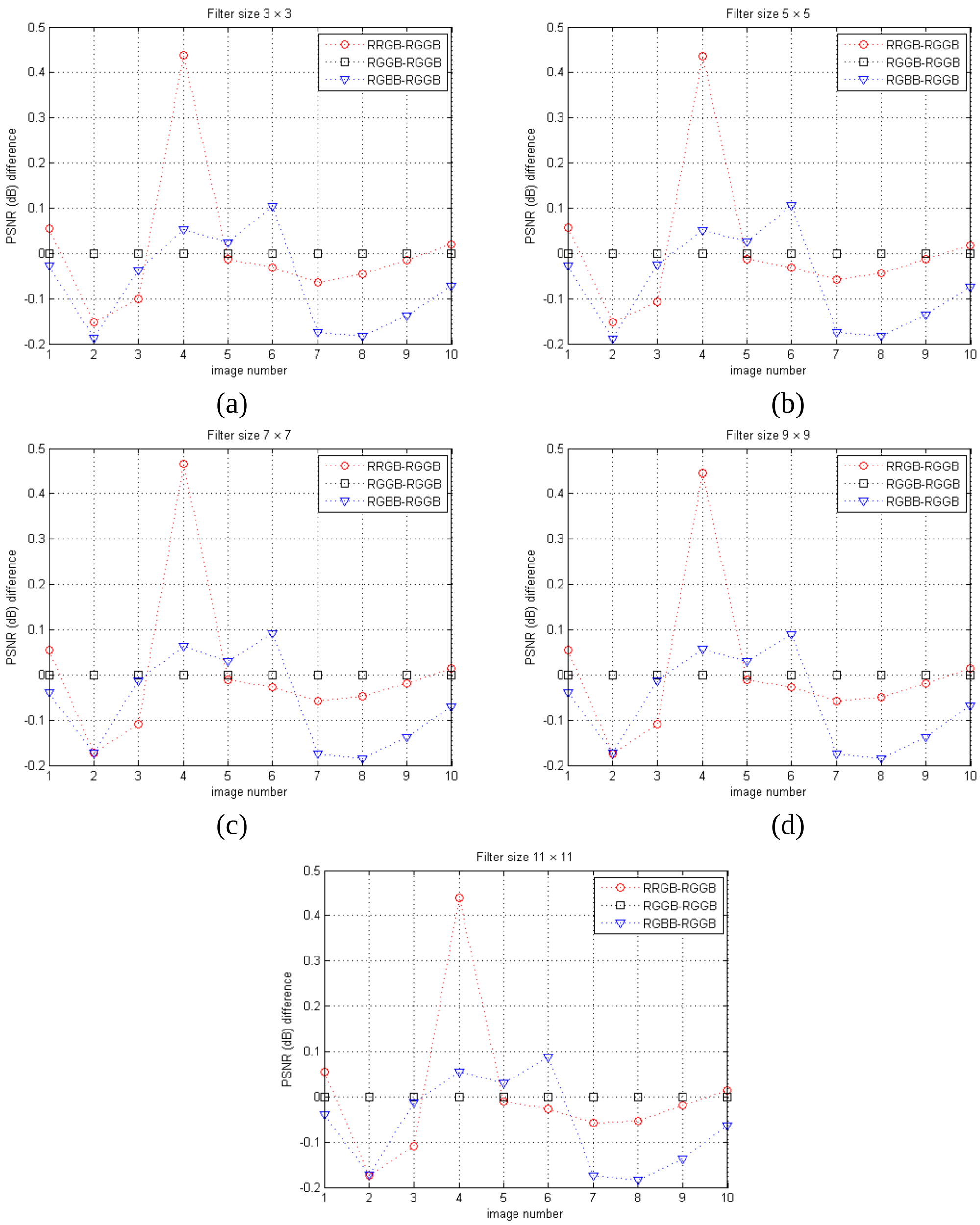


(d) (e) (f)

Figure 7. Reconstructed images of RGGB patterned #9 and #10 images. (a) Original images, (b) 3×3, (c) 5×5, (d) 7×7, (e) 9×9, and (f) 11×11

Figure 8. Reconstructed images of RGBB patterned #9 and #10 images. (a) Original images, (b) 3×3, (c) 5×5, (d) 7×7, (e) 9×9, and (f) 11×11

Figure 9 and Figure 10 show CPSNR and SCIELAB results.



(e)

Figure 9. Average CPSNR results (difference between each color pattern with RGGB pattern) for 10 tested images. (a) 3×3, (b) 5×5, (c) 7×7, (d) 9×9, and (d) 11×11

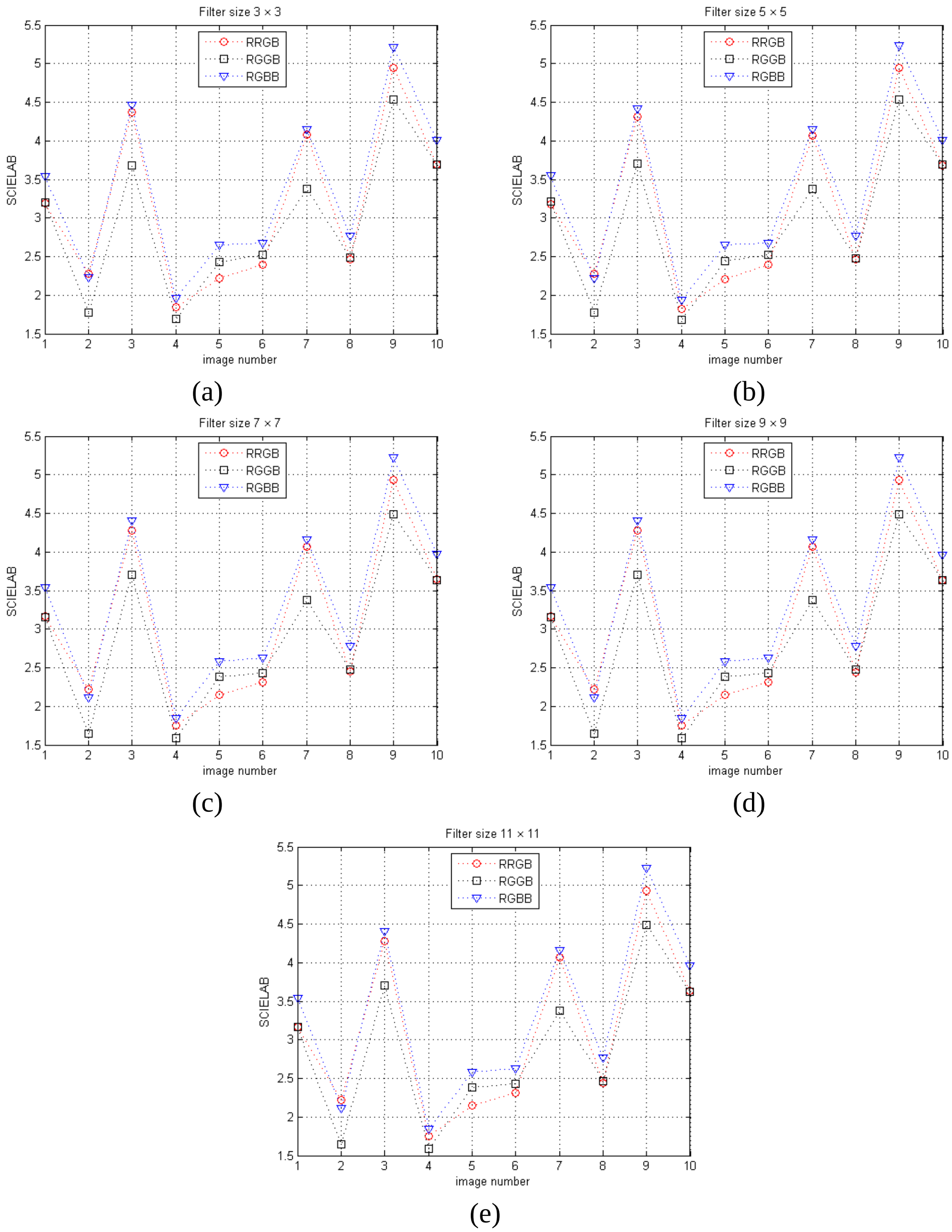


Figure 10. Average SCIELAB results for 10 tested images. (a) 3×3, (b) 5×5, (c) 7×7, (d) 9×9, and (d) 11×11

5. Conclusions

As described in the paper, digital cameras utilize a CFA to take the colors of the scene. In this paper, we studied the influence between filter size and color configuration. We examined performance of the various filters for color interpolation in terms of CPSNR and S-CIELAB. The simulation results show that the proposed filters yield great objective and subjective performance.

Acknowledgements

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Authors

Gwanggil Jeon received the BS, MS, and PhD (summa cum laude) degrees in Department of Electronics and Computer Engineering from Hanyang University, Seoul, Korea, in 2003, 2005, and 2008, respectively.

From 2008 to 2009, he was with the Department of Electronics and Computer Engineering, Hanyang University, from 2009 to 2011, he was with the School of Information Technology and Engineering (SITE), University of Ottawa, as a postdoctoral fellow, and from 2011 to 2012, he was with the Graduate School of Science & Technology, Niigata University, as an assistant professor. He is currently an assistant professor with the Department of Embedded Systems Engineering, Incheon National University, Incheon, Korea. His research interests fall under the umbrella of image processing, particularly image compression, motion estimation, demosaicking, and image enhancement as well as computational intelligence such as fuzzy and rough sets theories. He was the recipient of the IEEE Chester Sall Award in 2007 and the 2008 ETRI Journal Paper Award.