Journal of Engineering Technology
Volume. 3, Jan. 2015, Pages 34-44
ORIGINAL ARTICLE

Design of Multiple Channel Color Filter Array

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Abstract. In this paper, we compare the intensity of different color filter array and describe the effect of each color filter array. The color filter array process is always carried out before every possible color image reproduction. Usually color filter array has three color channels, red, green, and blue, and recently panchromatic component is newly used for giving higher intensity for conventional color filter array. We show how color filter array works and how we generate color filter array passed image. We investigate the changes of intensity in each shape of color filter array, which is shown in simulation results section. The tested dataset is McM imageset.

Keywords: Color filter array, image processing, color interpolation, intensity

1 Introduction

A color filter array (CFA) is a mosaic of small color filters located over the pixel sensors of an image sensor to obtain primary color information [1-4]. In general, the digital color image system employs an image sensor to capture the intensity of CFA pixel with different primary colors. The color filter is required because general photosensors detect light intensity without identifying wavelength [5-10]. Therefore, color information cannot be discerned. Every digital image sensor operates by storing light in a CFA of photosites [11,12]. When the exposure process starts, each photosite is open to gather incoming light [13-15]. After the exposure process finishes, the quantity of each photosite is numbered and the obtained number is read as a numerical intensity value of an image pixel.

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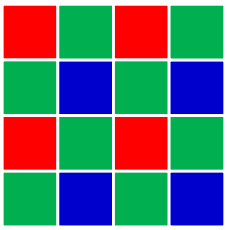

Figure. 1. Bayer color filter array.

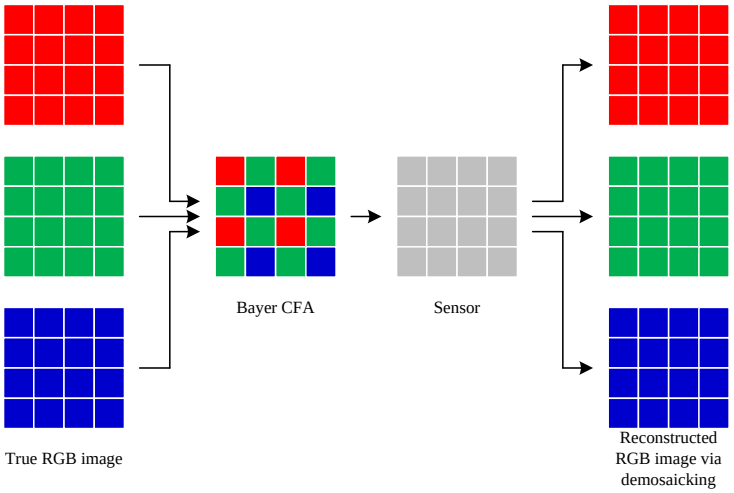

Figure. 2. Illustration of digital color image system: from image acquisition and color interpolation.

Normally CFA has three primary colors, red, green, and blue [19-29]. Figure 1 shows Bayer CFA which is one of the most popular CFAs, which consists of four pixels in a pair, each pair has 1 red, 2 greens, and 1 blue. As each pixel of pair has only 1 primary color, the other two missing components must be restored by color interpolation method, which is called demosaicking (Fig. 2) [16-18].

The rest of paper is organized as follows. Section 2 descries CFA generation process and shows various CFA patterns. Section 3 shows the simulation results and conclusion remarks are described in Section 4.

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2 Color filter array generation and investigation of various cfa patterns

As described in Section 1, digital camera captures only one primary color at each position in a various CFA pattern. Nowadays, unlike CFA sensors, panchromatic sensors are used to pay more attention on intensity values. The reason behind this idea is that human visual system is more sensitive to contrast than absolute luminance, and more sensitive to luminance than color information. To generate colors from CFA, one may use layers.

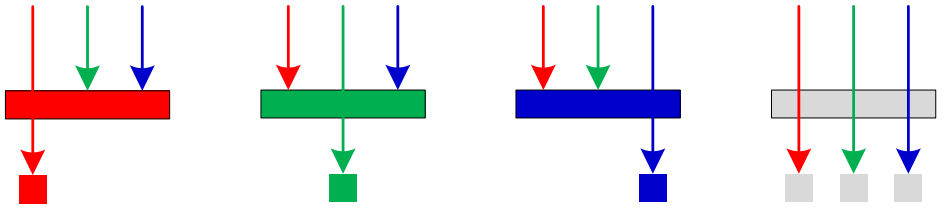

Figure. 3. Filter arrangement: (a) red filter, (b) green filter, (c) blue filter, and (d) panchromatic filter.

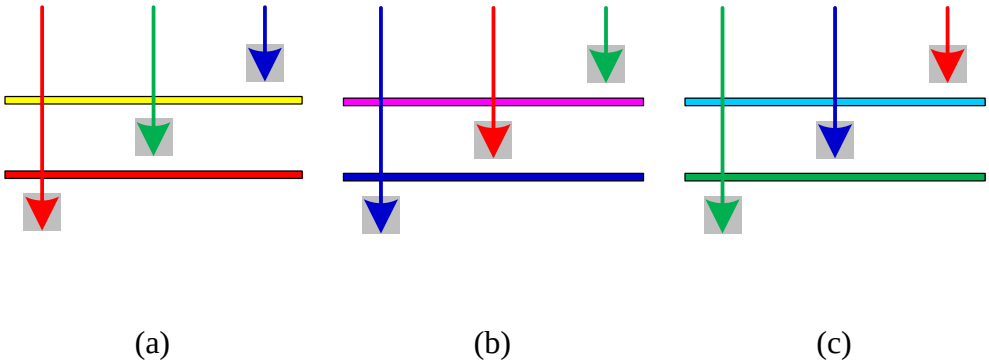

Figure. 4. CFA generation process using (a) yellow and red filters, (b) magenta and blue filters, and (c) cyan and green filters.

By combining layers of filters only certain colors can be passed. Figure 3(a-c) show filter arrangement where a color filter passes only the same color components. Figure 3(d) shows panchromatic filter which passes every color of the light. Figure 4 shows the CFA generation process using (a) yellow and

red filters, (b) magenta and blue filters, and (c) cyan and green filters. Figure 5 shows the RGB color model for light.

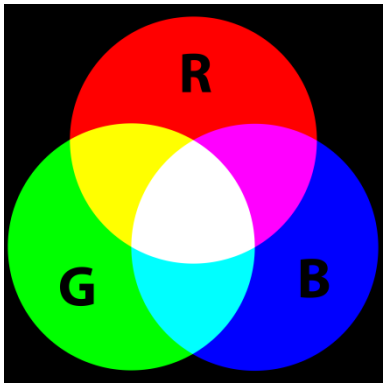

Figure. 5. RGB color model for light.

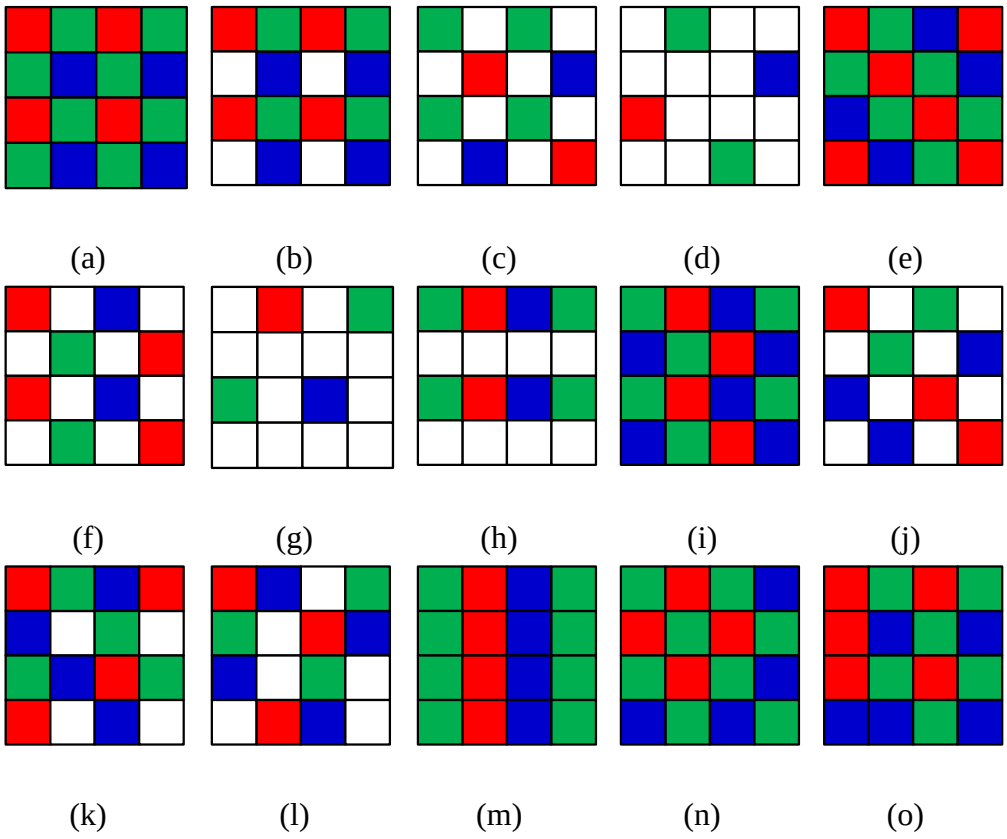

Figure. 6. Various 4x4 size color filter arrays: (a) P_A to (o) P_O.

For example, the yellow filter passes red and green wavelengths, magenta filter passes red and blue wavelengths, and cyan filter passes green and blue wavelengths, respectively. The panchromatic filter is sensitive to all wavelengths therefore it passes all color information. Thus, one can use two filters cyan filer to restrict red wavelength, and followed by green filter to restrict blue wavelength. Based on this Using this fundamental law, combining layers of filters can sequentially remove one color and another from entering lights.

There have number of color filter arrays, which are shown in Fig. 6. Figure 6(a) represents Bayer filter which is very common RGB filter, with 1 red and blue, and 2 green components. Therefore the pattern size of the pair is 2x2. Figure 6(b) is RGBW filter, which is Bayer-like pattern with 1 green, blue, red, and white component. Notice that white component is panchromatic sensor which passes all wavelengths. The CFA with panchromatic sensors are originally proposed by Kodak, and normally half of pixels are panchromatic sensors.

We named each CFA with P_A to P_O. Table 1 shows the intensity of each CFA, which is calculated by Eq. (1).

$$\text{intensity} = \frac{R_{\#} + G_{\#} + B_{\#}}{3} + W_{\#}. \quad (1)$$

Table 1. Number of Pixels in 4x4 Pair and Each Pattern's Intensity

	Number of pixels in 4x4 pair				
Pattern type	R	G	B	W	Intensity
P_A	4	8	4	0	5.33
P_B	4	4	4	4	8.00
P_C	2	4	2	8	10.67
P_D	1	1	1	13	14.00
P_E	6	6	4	0	5.33
P_F	4	2	2	8	10.67
P_G	1	2	1	12	13.33
P_H	2	4	2	8	10.67
P_I	4	6	6	0	5.33
P_J	3	2	3	8	10.67

P_K	4	4	4	4	8.00
P_L	3	3	4	6	9.33
P_M	4	8	4	0	5.33
P_N	4	8	4	0	5.33
P_O	5	6	5	0	5.33

Figure 7 shows an example of intensity values for 1st McM dataset image. Figures 7(*n*), 7(*b*), and 7(*n*) stand for P_A, P_B, and P_N CFA patterns, respectively.

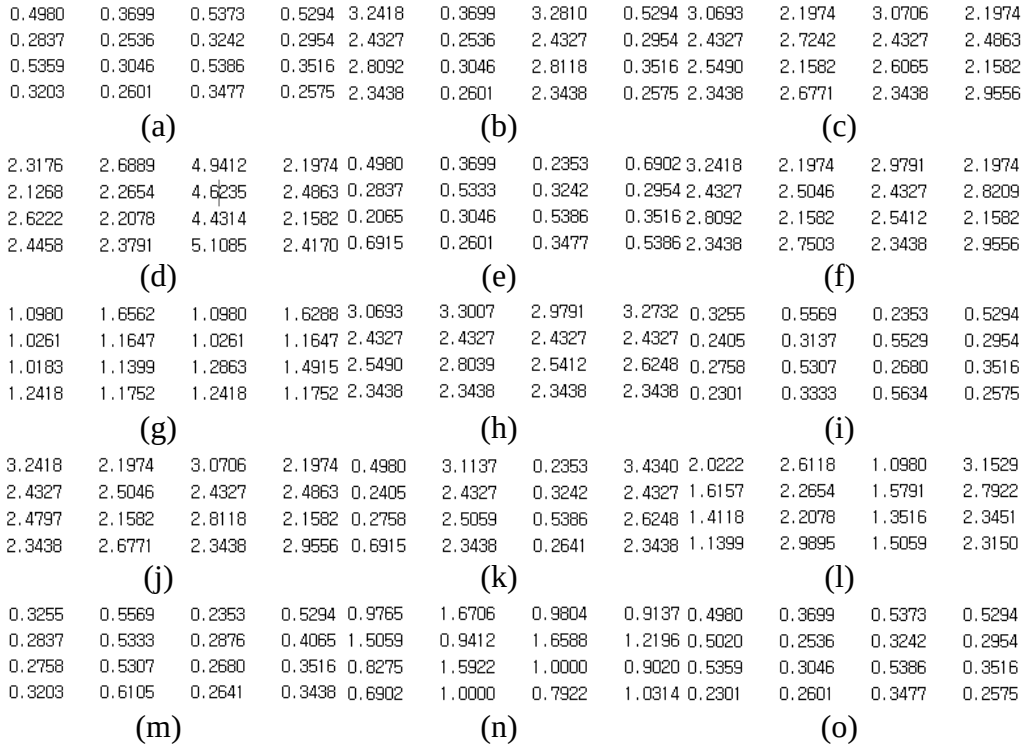

Figure. 7. Intensity for different CFA patterns for 1st McM image: (a) to (o) are patterns P_A to P_O.

3 Experimental Results

In this Section, our method is tested on 18 McM imageset by generating various CFA patterned image. The dataset is shown in Fig. 8. Tables 2 and 3 show the intensity for each CFA patterns.

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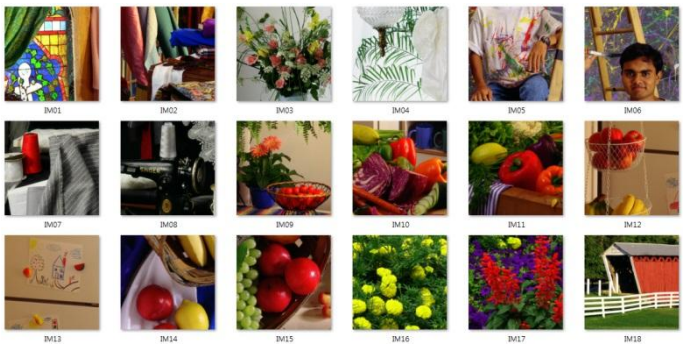

Figure. 8. The used dataset: McM image.

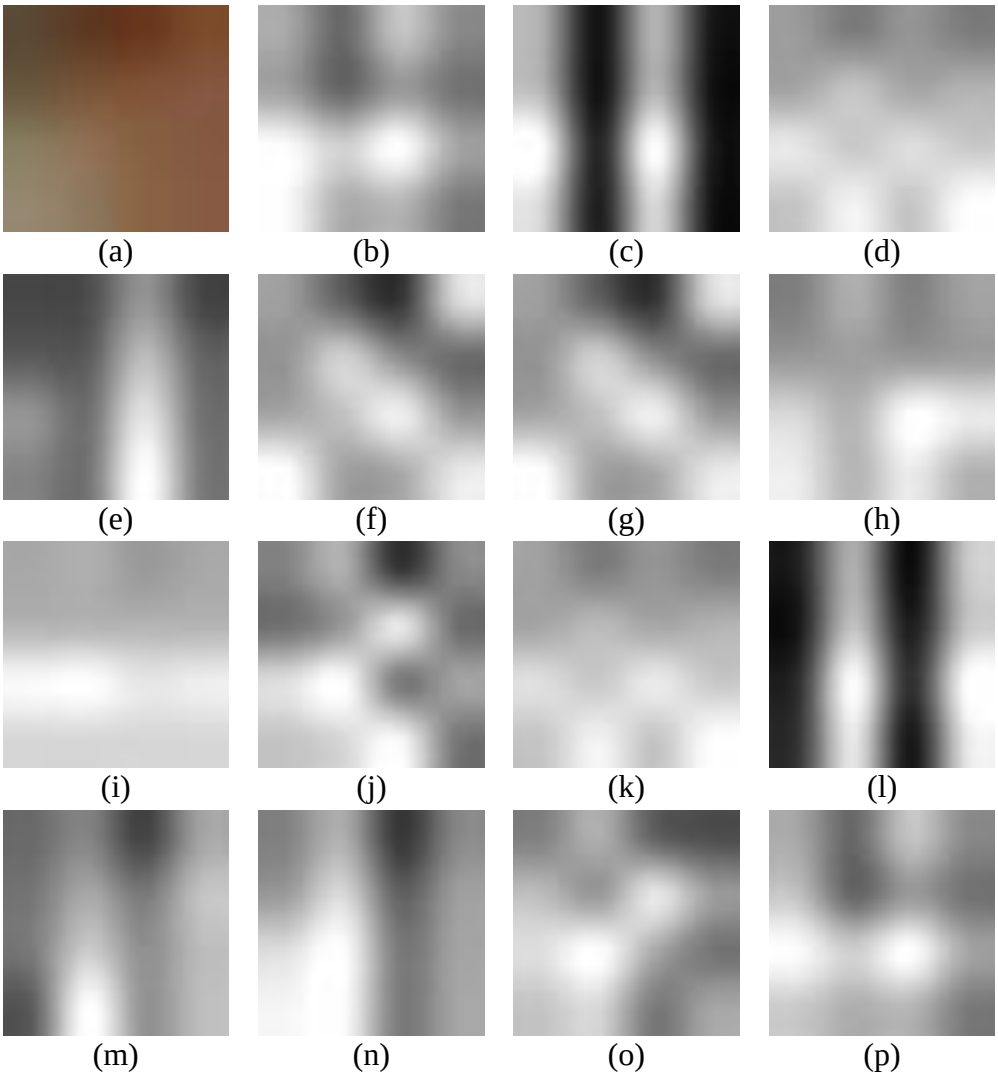

Figure. 9. Various 4x4 size color filter arrays: (a) original image and (b) P_A to (p) P_O.

Figure 9 shows the original image and its corresponding CFA images P_A to P_O. Note that color image is original image.

4 conclusions

This paper compared the intensity of different color filter array and described the effect of various CFA. The CFA process is requested before the demosaicking application. Various combinations of CFA patterns are introduced and the results of number of pixels in 4x4 pair is described. The simulation results were obtained on McM dataset.

Table 2. Each Pattern's Intensity

Image number	P_A	P_B	P_C	P_D	P_E	P_F	P_G	P_H
1	6.008	24.319	40.403	47.417	6.469	40.867	19.633	42.247
2	5.778	21.272	38.527	47.238	6.182	38.861	19.892	36.672
3	6.179	22.340	40.454	48.795	6.420	40.648	21.125	38.663
4	12.835	48.761	82.834	96.724	12.746	82.749	40.655	84.702
5	8.114	30.401	52.444	62.324	8.354	52.718	26.082	52.464
6	5.720	21.910	37.856	45.065	5.992	38.193	18.865	38.039
7	3.246	12.890	22.928	28.042	3.685	23.358	11.838	22.208
8	0.320	1.078	1.908	2.292	0.292	1.881	0.970	1.885
9	6.892	25.293	44.005	52.455	6.983	44.071	22.048	43.897
10	3.027	10.553	18.597	22.328	3.154	18.817	9.468	18.284
11	2.718	10.677	18.792	22.799	3.146	19.158	9.450	18.498
12	3.680	14.936	25.693	30.658	4.252	26.258	12.791	25.741
13	8.224	30.647	53.247	63.502	8.508	53.529	26.678	53.136
14	5.991	23.076	39.790	47.488	6.092	39.875	19.801	39.903
15	2.869	11.044	18.603	21.812	3.061	18.894	9.148	19.193
16	5.178	17.203	29.569	34.305	4.933	29.293	14.635	30.119
17	3.427	13.370	23.361	28.158	3.847	23.916	11.945	23.135
18	5.865	21.961	38.672	46.244	6.171	38.822	19.297	38.136
Average	5.337	20.096	34.871	41.536	5.572	35.106	17.462	34.829

Table 3. Number of Pixels in 4x4 Pair and Each Pattern's Intensity

Image number	P_I	P_J	P_K	P_L	P_M	P_N	P_O
1	5.860	40.492	24.299	32.404	6.123	5.901	6.136
2	5.626	38.631	21.427	29.552	5.784	5.770	5.889
3	6.044	40.472	22.515	31.320	6.199	6.176	6.171
4	12.809	82.745	48.608	66.988	12.827	12.830	12.716
5	7.818	52.492	30.278	41.352	8.111	8.055	8.093
6	5.616	37.919	21.966	29.961	5.761	5.740	5.756
7	3.237	23.132	12.949	17.688	3.254	3.238	3.414
8	0.312	1.880	1.086	1.459	0.328	0.335	0.302
9	6.608	43.903	25.306	34.533	6.888	6.907	6.799
10	2.614	18.507	10.554	14.328	2.987	3.042	2.945
11	2.557	18.788	10.724	14.480	2.776	2.778	2.735
12	3.529	25.895	14.919	20.235	3.660	3.665	3.902
13	7.890	53.220	30.656	41.804	8.234	8.233	8.187
14	6.102	39.899	23.050	31.448	5.975	5.990	6.103
15	2.647	18.604	11.029	14.848	2.820	2.885	2.846
16	4.348	29.061	17.180	23.395	5.140	5.192	4.748
17	3.201	23.484	13.438	18.422	3.490	3.439	3.566
18	5.800	38.667	22.031	29.829	5.852	5.869	5.833
Average	5.146	34.877	20.112	27.447	5.345	5.336	5.341

Acknowledgment

This work was supported by the National Research Foundation of Korea(NRF) Grant funded by the Korean Government(MSIP)(2014025627)

References

1. Bayer, B., "Color imaging array," U.S. Patent 3971065, July 1976.
2. Gunturk, B. K., Glotzbach, J., Altunbasak, Y., Schafer, R. W., Mersereau, R. M., "Demosaicking: color filter array interpolation," IEEE. Signal Processing Magazine, **22**(1): 44-54, 2005.
3. Gunturk, B. K., "Demosaicking: color filter array interpolation," IEEE Signal Processing Magazine, **22**(1): 44-54, 2005.
4. Chung, K.-H., Chan, Y.-H., "A lossless compression scheme for bayer color filter array images." IEEE Trans Image Process, **17**(2): 134–44, 2008.
5. Ramanath, R., Snyder, W. E., Yoo, Y., Drew, M. S., "Color image processing pipeline," IEEE Signal Process. Mag., **22**: 34–43, 2005.
6. Chung, K. -L., Yang, W. -J. Chen, P. -Y., Yan, W. -M., Fuh, C. -S., "New joint demosaicing and zooming algorithm for color filter array," IEEE Trans. Consumer Electronics, **55**(3): 1477-1486, 2009.
7. Xie, X., Li, G., Wang, Z., Zhang, C., Li, D., Li, X., "A novel method of lossy image compression for digital image sensors with bayer color filter arrays," in IEEE ISCAS2005, pp. 4995–4998.
9. Gunturk, B. K., Altunbasak, Y., Mersereau, R. M., Color plane interpolation using alternating projections, IEEE Trans. Image Processing, **11**(9): 997-1013, 2002.
10. Lian, N., Chang, L., Tan, Y., Zagorodnov, V., "Adaptive filtering for color filter array demosaicking," IEEE Trans. Image Processing, **16**(10): 2515-2525, 2007.
11. Alleysson, D., Süsstrunk, S., Hérault, J., "Linear demosaicking by the human visual system," IEEE Trans. Image Processing, **14**(4): 439-449, 2005.
12. Menon, D., Calvagno, G., "Regulation approaches to Demosaicking," IEEE Trans. Image Processing, **18**(10): 2209-2220, 2009.
13. Leung, B., Jeon, G., Dubois, E., "Least-squares luma-chroma demultiplexing algorithm for Bayer demosaicking," IEEE Trans. Image Processing, **20**(7): 1885-1894, 2011.
14. Zhang, L., Wu, X., "Color demosaicking via directional linear minimum mean square-error estimation," IEEE Trans. Image Processing, **14**(12): 2167-2178, 2005.
15. Hirakawa, K., Parks, T. W., "Adaptive homogeneity-directed demosaicing algorithm," IEEE Trans. Image processing, **14**(3): 360-369, 1997.

16. Hirakawa, K., Parks, T. W., "Adaptive homogeneity-directed demosaicing algorithm," IEEE Transactions on Image Processing, **14**(3): 360–369, 2005.

17. Battiato, S., Buemi, A., Torre, L. D., Vitali, A., "Fast vector quantization engine for cfa data compression," in Proceedings of IEEE-EURASIP Workshop on Nonlinear Signal and Image Processing, NSIP, 2003.

18. Zhang, X., Wandell, B. A., "A spatial extension of cielab for digital color image reproduction," in Proceedings of the SID Symposiums, 1996, pp. 731–734.

19. Fang, Y., "Joint source-channel estimation using accumulated LDPC syndrome," IEEE Commun. Lett., **14**(11): 1044-1046, Nov. 2010.

20. Fang, Y., "EREC-based length coding of variable-length data blocks," IEEE Trans. Circ. Syst. Video Technol., **20**(10): 1358-1366, Oct. 2010.

21. Fang, Y., "Distribution of distributed arithmetic codewords for equiprobable binary sources," IEEE Signal Process. Lett., **16**(12), 1079-1082, Dec. 2009.

22. Fang, Y., "Crossover probability estimation using mean-intrinsic-LLR of LDPC syndrome," IEEE Commun. Lett., **13**(9): 679-681, Sep. 2009.

23. Fang, Y., Jeon, G., and Jeong, J., "State-information-assisting EREC," IEEE Signal Process. Lett., **16**(4): 260-263, Apr. 2009.

24. Fang, Y. and Jeong, J., "Correlation parameter estimation for LDPC-based Slepian-Wolf coding," IEEE Commun. Lett., **13**(1): 37-39, Jan. 2009.

25. Jeon, G., Anisetti, M., Bellandi, V., and Jeong, J., "Fuzzy rule-based edge-restoration algorithm in HDTV interlaced sequences," IEEE Trans. Consumer Electronics, **53**(2): 725-731, May 2007.

26. Jeon, G., Anisetti, M., Bellandi, V., Damiani, E., and Jeong, J., "Rough Sets-Assisted Subfield Optimization for Alternating Current Plasma Display Panel", IEEE Trans. Consumer Electronics, **53**(3): 825-832, Aug. 2007.

27. Jeon, G., Anisetti, M., Bellandi, V., Damiani, E., and Jeong, J., "Fuzzy Weighted Approach to Improve Visual Quality of Edge-Based Filtering" IEEE Transactions on Consumer Electronics, November 2007.

28. Jeon, G., Anisetti, M., Kim, D., Bellandi, V., Damiani, E., and Jeong, J., "Fuzzy rough sets hybrid scheme for motion and scene complexity adaptive deinterlacing", IMAVIS Image and Vision Computing Journal, **27**(4): 425-436, March 2009.

29. Jeon, G., Anisetti, M., and Kang, S., "A Rank-Ordered Marginal Filter for Deinterlacing" Sensors, **13**(3): 3056-3065, March 2013.