Joint demosaicing of colour and polarisation from filter arrays

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ABSTRACT

This work considers the joint demosaicing of colour and polarisation image captured with a Colour and Polarisation Filter Array sensor. The Linear Minimum Mean Square Error (LMMSE) algorithm is applied to this case, and its performance is compared to the state-of-the-art Edge-Aware Residual Interpolation algorithm. Results show that the generic demosaicing LMMSE method gives statistically higher PSNR scores on the largest tested database.

CPFA

- The Colour and Polarisation Filter Array (CPFA) sensor with 12 channels,
- A commercial implementation is the SONY IMX250 MYR.

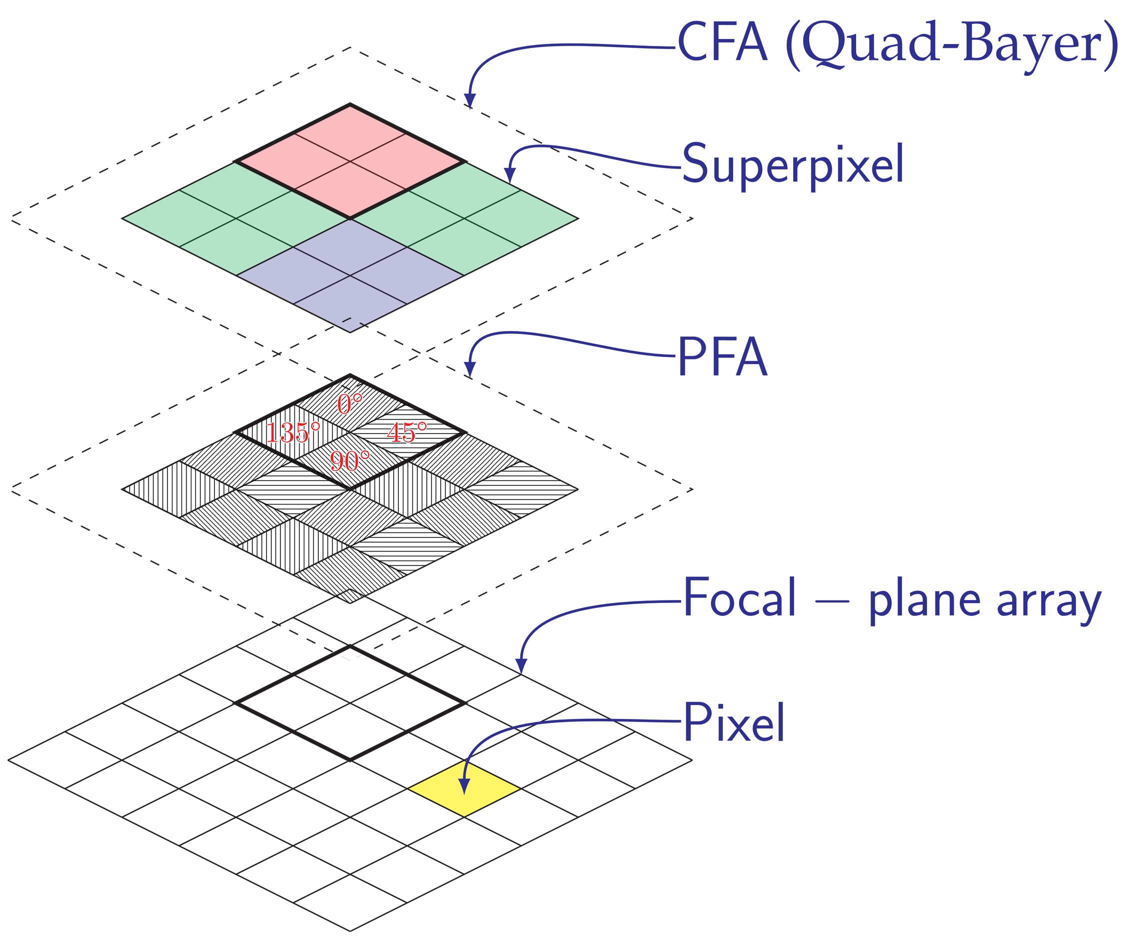

Figure 1: The CPFA sensor case. The 4×4 super-pixel is composed of 4 linear polarization filters and 3 spectral filters.

LMMSE (1)

We apply the LMMSE algorithm [1] for the case of CPFA. Be $\boldsymbol{Y}$ the full-resolution image, and $\boldsymbol{X}$ the mosaiced CPFA image.

The algorithm applies a vectorization: the full-resolution data $\boldsymbol{Y}$ is unfolded by superpixel, giving the matrices $\boldsymbol{y}$.

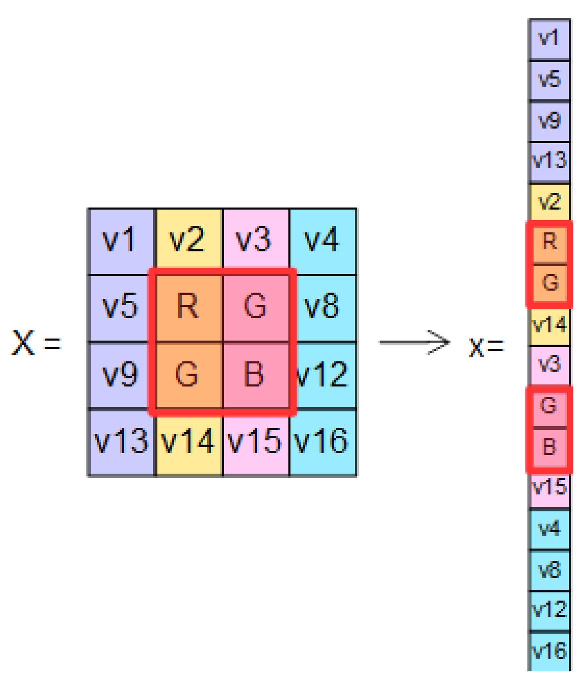

Figure 2: Example of the unfolding columns by columns of a CFA superpixel of 2×2 pixels (red square) with a neighborhood of 4×4 pixels.

The same principle is applied to CPFA to unfold each 4×4 superpixel with a neighborhood of 10×10, and construct y.

QUANTITATIVE EVALUATION

	DB1 (150Mo)				DB2 (530Mo)				DB3 (1.4Go)			
	LMMSE		EARI		LMMSE		EARI		LMMSE		EARI	
	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
$I_{0,R}$	35.25	3.79	**35.49**	4.45	42.98	4.21	**44.65**	4.29	**39.34**	4.15	37.70	4.81
$I_{45,R}$	36.20	3.78	**36.36**	4.10	42.95	4.38	**44.92**	4.24	**39.16**	4.08	37.20	4.78
$I_{90,R}$	36.25	3.76	**36.58**	4.27	43.00	4.44	**45.02**	4.27	**39.76**	4.04	37.97	4.52
$I_{135,R}$	35.34	3.87	**35.47**	4.63	43.10	4.22	**44.91**	4.30	**38.88**	4.00	37.30	4.63
$I_{0,G}$	**40.21**	3.50	39.78	3.93	44.98	4.75	**45.38**	4.74	**44.11**	4.69	42.77	4.83
$I_{45,G}$	**41.32**	3.01	40.72	2.93	45.24	4.51	**46.03**	4.54	**43.37**	4.69	41.71	4.88
$I_{90,G}$	**41.36**	2.97	40.99	2.88	45.25	4.58	**46.18**	4.66	**44.61**	4.54	43.07	4.67
$I_{135,G}$	**40.12**	3.51	39.63	3.97	45.20	4.65	**45.71**	4.73	**42.95**	4.59	41.58	4.87
$I_{0,B}$	36.86	2.69	**37.27**	2.96	43.05	4.94	**44.89**	5.14	**41.00**	5.00	40.36	5.17
$I_{45,B}$	37.26	2.37	**37.42**	2.38	43.75	4.71	**45.42**	4.70	**40.35**	5.05	39.61	5.29
$I_{90,B}$	**37.31**	2.40	37.27	2.53	43.80	4.73	**45.47**	4.75	**41.01**	4.98	40.52	5.23
$I_{135,B}$	**36.73**	2.84	36.40	3.07	43.24	4.91	**45.10**	5.10	**40.23**	5.05	39.62	5.41

Figure 1: Average μ and standard deviation σ of PSNR, computed individually in a leave-one-out manner and by channel. Best mean values by database and by channel are highlighted in bold fonts.

LMMSE (2)

The **mosaicing matrix** $\boldsymbol{M}$ is computed, such as:

$$\boldsymbol{x} = \boldsymbol{M}\boldsymbol{y} \, , \tag{1}$$

where $\boldsymbol{x}$ is the unfolded matrix $\boldsymbol{X}$. The mosaicing matrix $\boldsymbol{M}$ is block-shift invariant.

The aim of demosaicing is to estimate $\hat{\boldsymbol{y}}$ from the observations $\boldsymbol{x}$, such that the estimate image is the most faithful to the reference matrix $\boldsymbol{y}$. This is achieved by the **demosaicing matrix** $\boldsymbol{D}$, which is a pseudo-inverse of $\boldsymbol{M}$, such that:

$$\hat{y} = \boldsymbol{D}\boldsymbol{x} \, . \tag{2}$$

$\boldsymbol{D}$ is computed with the Wiener filtering approach on a dataset of k images:

$$\boldsymbol{D} = E_i\{\boldsymbol{y}\boldsymbol{x}^t(\boldsymbol{x}\boldsymbol{x}^t)^{-1}\} \, , \tag{3}$$

where E is the expectation, and $i \in [1, k]$ indexes the image in the dataset.

EXPERIMENT

The experiment is conducted over three existing database of full-resolution spectropolarimetric images.

- **DB1**: Lapray *et al.* [2] (DB1, 10 images, 150Mo of data),
- **DB2**: Qiu *et al.* [4] (DB2, 40 images, 530Mo of data),
- **DB3**: Monno *et al.* [3] (DB3, 40 images, 1.4Go of data).

We demosaic the images using two methods:

- Our application of the LMMSE method to CPFA [1],
- The Edge-Aware Residual Interpolation (EARI) [3].

QUALITATIVE EVALUATION

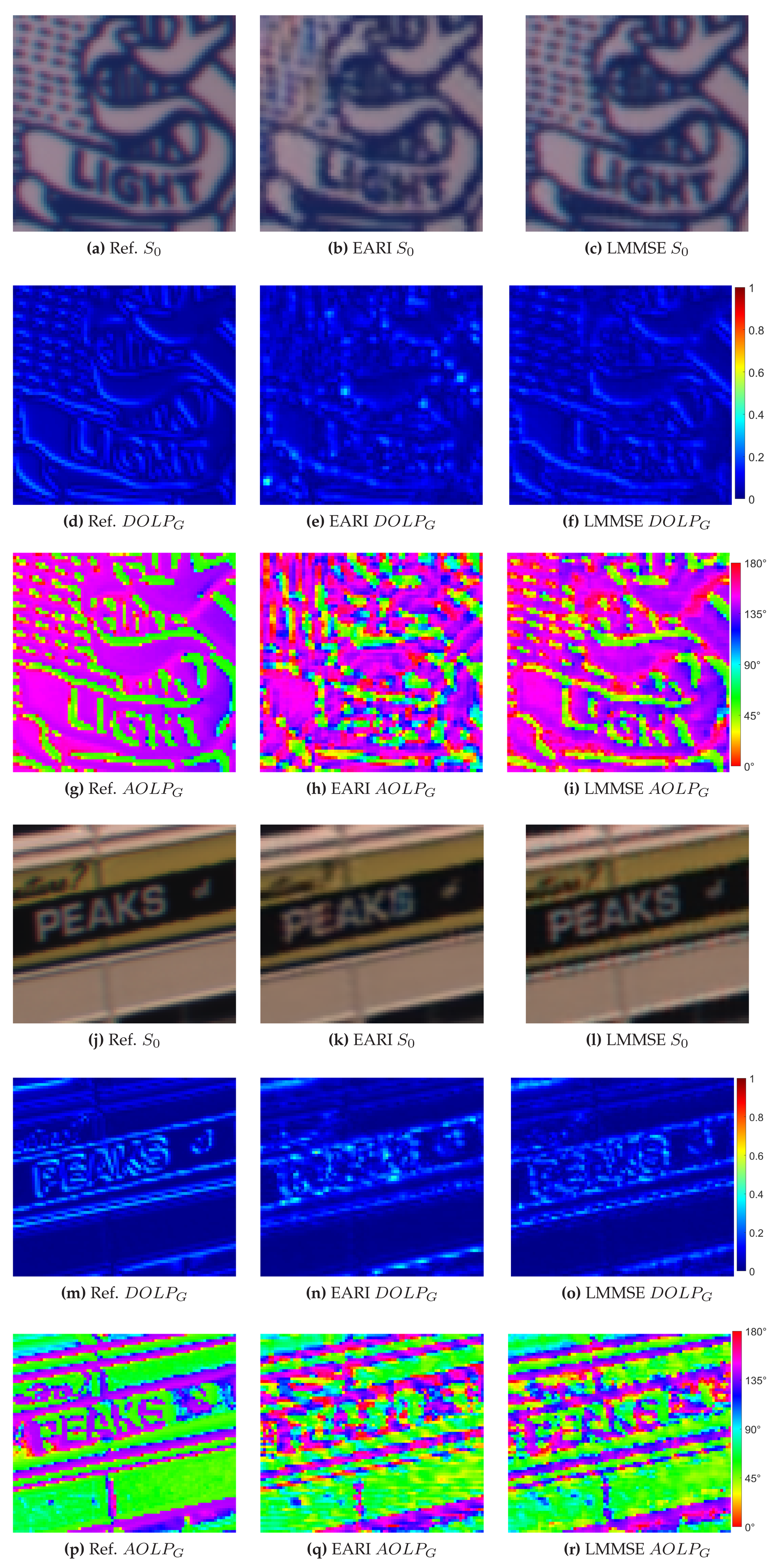

Figure 2: Visualization of the S_0 Stokes component images, and the DOLP (Degree Of Linear Polarization) and AOLP (Angle Of Linear Polarization). Region of interest of images from [3].

REFERENCE

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[3] M. Morimatsu, Y. Monno, M. Tanaka, and M. Okutomi. Monochrome and color polarization demosaicing using edge-aware residual interpolation. In *2020 IEEE International Conference on Image Processing (ICIP)*, pages 2571–2575, 2020.

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