# Adaptive Residual Interpolation for Color Image Demosaicking

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**Source Code Available !!**
http://www.ok.ctrl.titech.ac.jp/res/DM/RI.html

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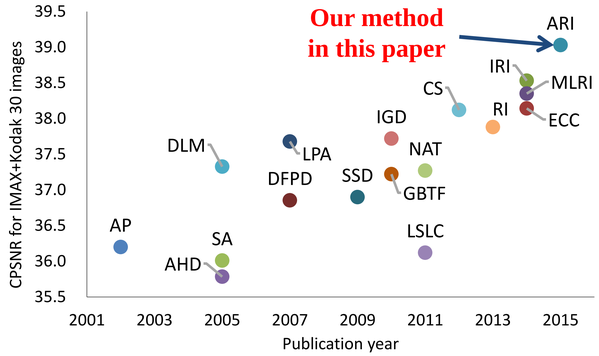
## Introduction

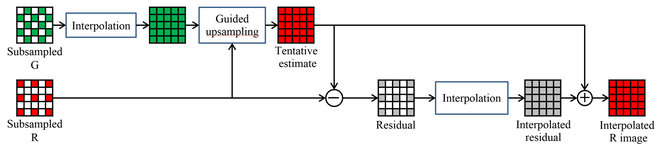
- Color image demosaicking plays an important role for acquiring high-quality color images.
- Bayer CFA is a de-facto standard CFA.
- Many algorithms have been proposed for the Bayer CFA every year.

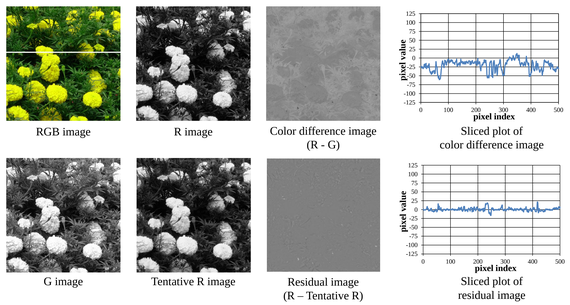

CPSNR performance for standard dataset

## Our Idea of Residual Interpolation

- Interpolation is performed in a **residual domain.**

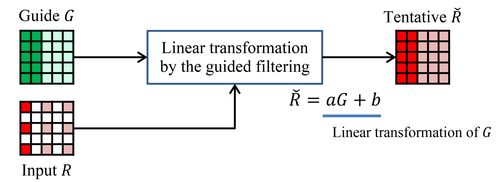



- Motivated by two observations;
  1. The residual image becomes smooth.
  2. Interpolation is more accurate for smooth images.




## Residual Interpolation Based Algorithms

- **RI: original residual interpolation [30] (ours in ICIP2013)**
  Direct minimization of residuals by guided filtering [33]
- **MLRI: minimized-Laplacian residual interpolation [31] (ours in EI2014)**
  Minimization of "Laplacian" energy of residuals by modified guided filtering



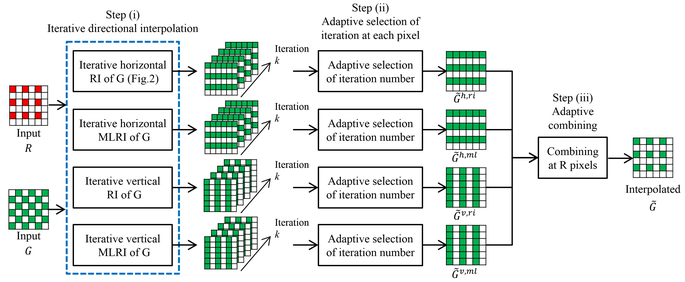

Cost function of the guided filtering

RI: $(a,b) = \min_{a,b}(aG + b - R)^2$

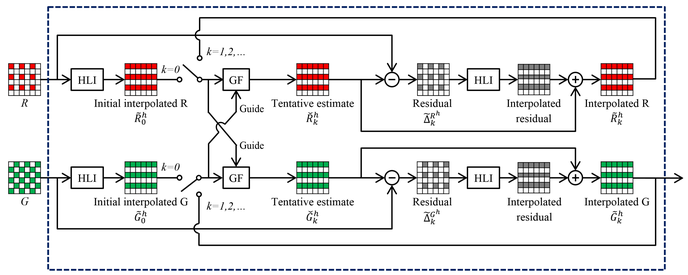
MLRI: $(a,b) = \min_{a,b} \Delta(aG + b - R)^2$ (Laplacian operator)

- **IRI: iterative residual interpolation [32] (Ye et. al. in ICIP2014)**
  Iterative update of the tentative estimate
- **Proposed ARI: adaptive residual interpolation (This paper in ICIP2015)**
  1. Adaptive (local) selection of the best iteration number
  2. Adaptive combination of the RI and the MLRI

### Overall flow of G interpolation




### Step (i): Iterative directional interpolation (horizontal)




### Find the best iteration number

$$k_{opt} = \min_k c^h_{(i,j),k} = \min_k \left(d^h_{(i,j),k} \cdot \delta d^h_{(i,j),k}\right)$$

Gradient

Cost of tentative estimation

$$d^h_{(i,j),k} = d^{R^h}_{(i,j),k} + d^{G^h}_{(i,j),k}$$

Where

$$d^{R^h}_{(i,j),k} = \check{R}^h_{(i,j),k} - \tilde{R}^h_{(i,j),k-1}$$

$$d^{G^h}_{(i,j),k} = \check{G}^h_{(i,j),k} - \tilde{G}^h_{(i,j),k-1}$$

Tentative estimate at k-th iteration

Previous result

### Weight Calculation

$$w^{h,ri}_{i,j} = 1/c^{h,ri}_{(i,j)}$$

$$w^{h,ml}_{i,j} = 1/c^{h,ml}_{(i,j)}$$

$$w^{v,ri}_{i,j} = 1/c^{v,ri}_{(i,j)}$$

$$w^{v,ml}_{i,j} = 1/c^{v,ml}_{(i,j)}$$

## Results

- **CPSNR for Kodak and IMAX 30 dataset**

**Table 1**. The average PSNR and CPSNR performances for the standard IMAX and Kodak datasets.

| Algorithm | IMAX | | | | Kodak | | | | IMAX+Kodak | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PSNR | | | CPSNR | PSNR | | | CPSNR | PSNR | | | CPSNR |
| | R | G | B | | R | G | B | | R | G | B | |
| AP [25] | 32.91 | 35.15 | 32.37 | 33.27 | 39.81 | 43.17 | 39.64 | 40.59 | 35.67 | 38.36 | 35.28 | 36.20 |
| SA [26] | 32.73 | 34.73 | 32.10 | 32.98 | 39.80 | 43.31 | 39.50 | 40.54 | 35.56 | 38.16 | 35.06 | 36.01 |
| AHD [18] | 33.00 | 36.98 | 32.16 | 33.49 | 38.81 | 40.84 | 38.42 | 39.22 | 35.32 | 38.52 | 34.66 | 35.78 |
| DLM [22] | 34.04 | 38.01 | 33.05 | 34.48 | 41.17 | 43.94 | 40.51 | 41.60 | 36.89 | 40.38 | 36.03 | 37.33 |
| LPA [24] | 34.36 | 37.88 | 33.30 | 34.72 | 41.66 | 44.46 | 41.00 | 42.12 | 37.28 | 40.51 | 36.38 | 37.68 |
| DFPD [19] | 33.80 | 37.21 | 33.00 | 34.27 | 40.26 | 42.54 | 39.86 | 40.72 | 36.39 | 39.34 | 35.74 | 36.85 |
| SSD [15] | 35.02 | 38.27 | 33.80 | 35.23 | 38.83 | 40.51 | 39.08 | 39.40 | 36.54 | 39.16 | 35.91 | 36.90 |
| GBTF [20] | 33.48 | 36.59 | 32.71 | 33.89 | 41.71 | **44.85** | 41.01 | 42.21 | 36.77 | 39.89 | 36.03 | 37.22 |
| IGD [28] | 34.33 | 37.38 | 33.46 | 34.70 | **41.72** | **44.85** | **41.10** | **42.26** | 37.29 | 40.37 | 36.51 | 37.72 |
| NAT [16] | 36.31 | 39.82 | 34.50 | 36.27 | 38.30 | 40.49 | 37.94 | 38.77 | 37.11 | 40.08 | 35.87 | 37.27 |
| LSLC [14] | 32.31 | 35.09 | 31.93 | 32.85 | 40.36 | 43.85 | 39.89 | 41.03 | 35.53 | 38.59 | 35.11 | 36.12 |
| CS [27] | 35.56 | 38.84 | 34.58 | 35.92 | 41.01 | 44.17 | 40.12 | 41.43 | 37.74 | 40.97 | 36.80 | 38.12 |
| ECC [29] | 36.67 | 39.99 | 35.31 | 36.78 | 39.87 | 42.17 | 39.00 | 40.14 | 37.95 | 40.86 | 36.79 | 38.12 |
| RI [30] | 36.07 | 39.99 | 35.35 | 36.48 | 39.64 | 42.17 | 38.87 | 39.99 | 37.50 | 40.86 | 36.76 | 37.88 |
| MLRI [31] | 36.35 | 39.90 | 35.36 | 36.62 | 40.59 | 42.97 | 39.86 | 40.94 | 38.04 | 41.13 | 37.16 | 38.35 |
| IRI [32] | 36.62 | 40.28 | 35.79 | 36.98 | 40.27 | 43.48 | 39.72 | 40.85 | 38.08 | 41.56 | 37.36 | 38.53 |
| Proposed | **37.41** | **40.72** | **36.05** | **37.52** | 40.81 | 43.66 | 40.21 | 41.31 | **38.77** | **41.90** | **37.72** | **39.03** |

- **Visual Comparison**


## Conclusion

- The ARI adaptively selects the best iteration number and combines the RI and the MLRI at each pixel.
- Experimental results demonstrate a clear improvement over existing algorithms.

## References

**Source Code:** http://www.ok.ctrl.titech.ac.jp/res/DM/RI.html

[30] D. Kiku, Y. Monno, M. Tanaka, and M. Okutomi, "Residual interpolation for color image demosaicking," in ICIP, 2013.
[31] D. Kiku, Y. Monno, M. Tanaka, and M. Okutomi, "Minimized-Laplacian residual interpolation for color image demosaicking," in EI, 2014.
[32] W. Ye and K. K. Ma, "Image demosaicing by using iterative residual interpolation," in ICIP, 2014.
[33] K. He et. al., "Guided image filtering," TPAMI, 2013.