Side Window Filtering

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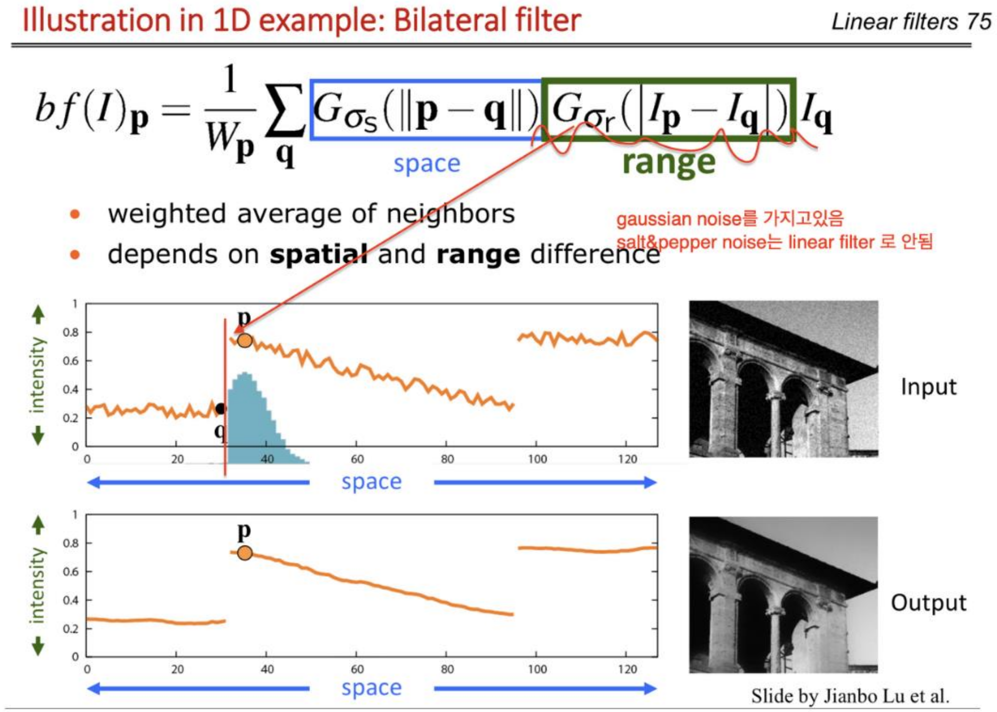
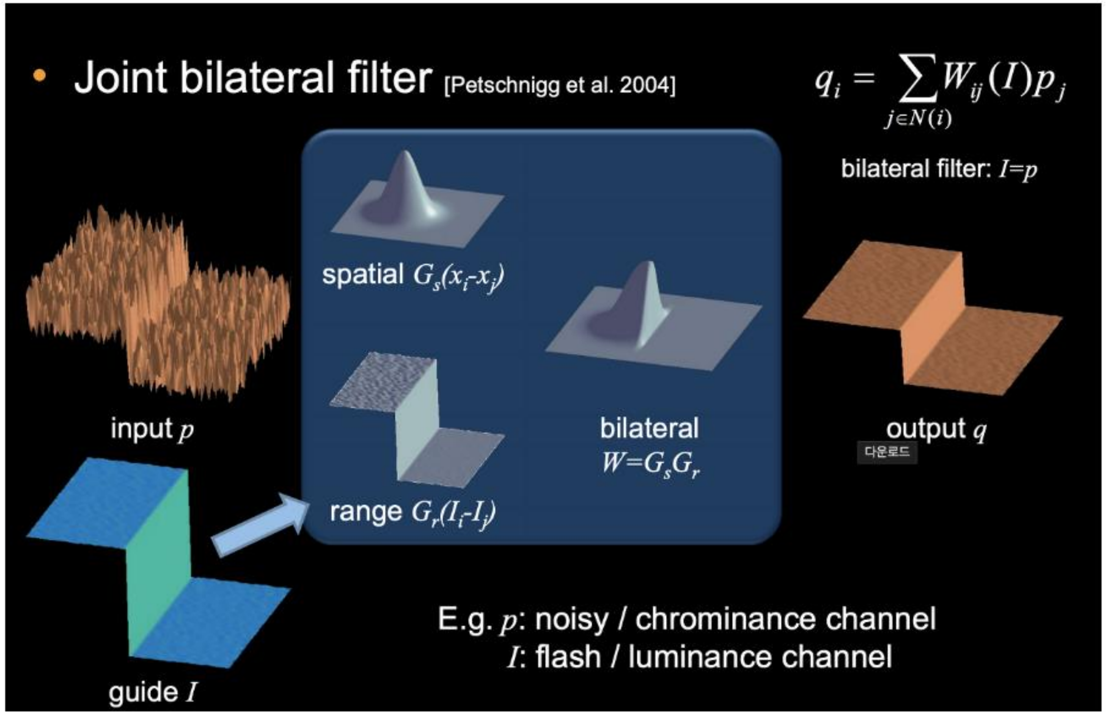
Backgrounds

Image filtering

1. **Linear approximation filtering: Gaussian filter, Box filter,**
2. **Non-linear approximation: bilateral filter, guided filter**

example: bilateral filter





Motivation

-To satisfy the linear assumption, center pixel should be approximated in the side windows

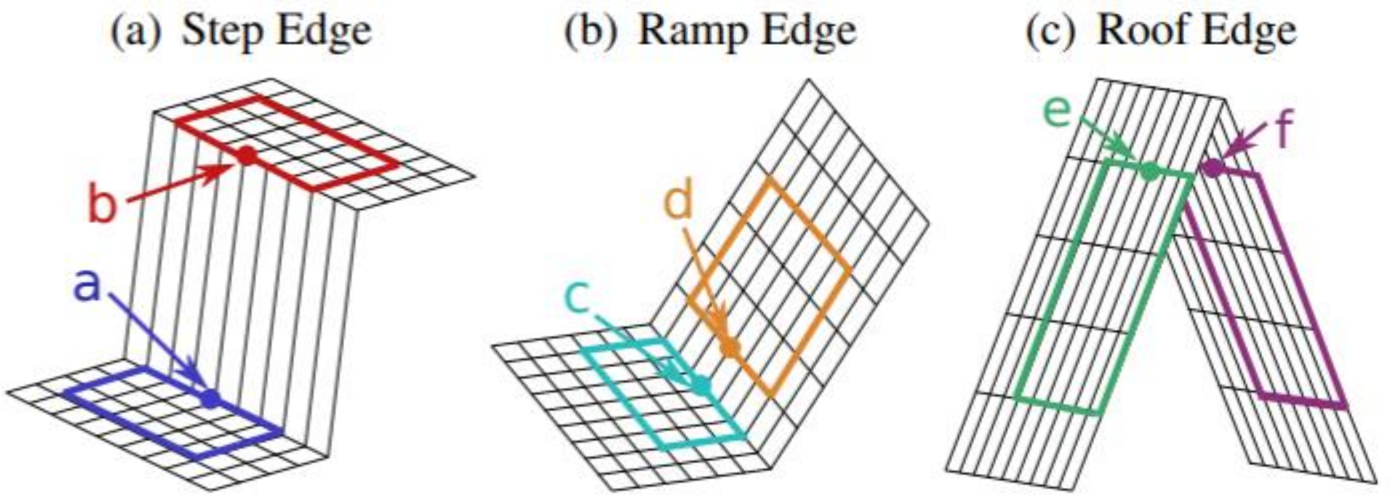


Figure 1. Model of ideal edges in 2D piecewise images. The pixel 'a'∼'f' are on edges or near edges. To satisfy the linear assumption, they should be approximated in the side windows which have the same colors with them, not the local windows centered at them.

Contribution

Propose an 'Side Window Filtering'(SWF) scheme

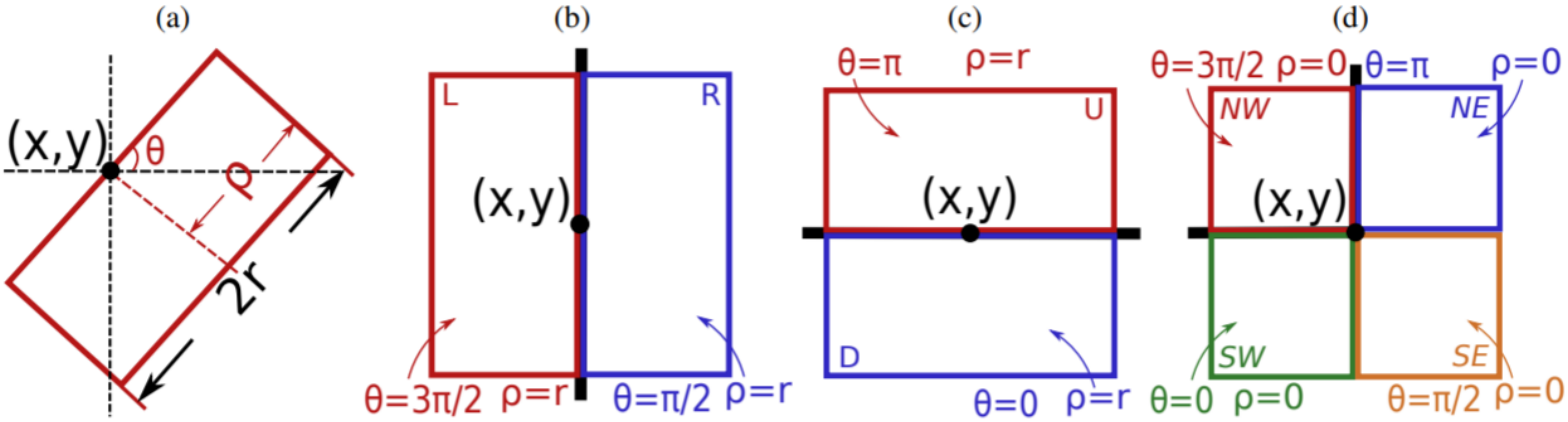
- Traditional linear filter methods can easily be implemented under the SWF framework

- SWF can effectively prevent artifacts color leakage in colorization by optimization

- SWF framework provides state of the art performances in a variety of real word applications including image smoothing, denoising, …

Method

Side window



$\rho \in \{0, r\}$

$\theta = \frac{k}{2}\pi, k \in \{0,1,2,3\}$

Method

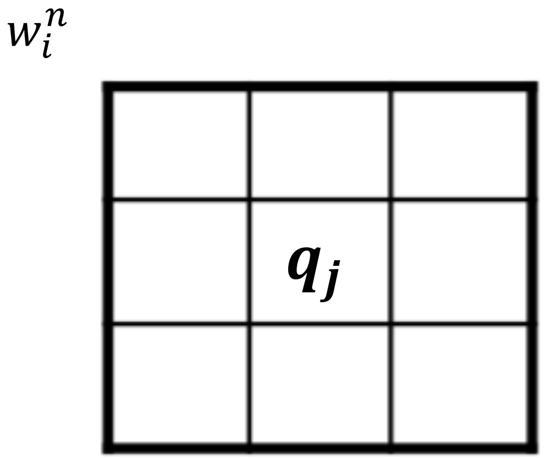
Algorithm 1 Calculate the SWF for each pixel

Require: w_{ij} is the weight of pixel j, which is in the neighborhood of the target pixel i, based on kernel function F. $S = \{L, R, U, D, NW, NE, SW, SE\}$ is the set of side window index.

1: $I_{\mathrm{n}} = \frac{1}{N_{\mathrm{n}}} \sum_{j \in \omega_i^{\mathrm{n}}} w_{ij} q_j$, $N_{\mathrm{n}} = \sum_{j \in \omega_i^{\mathrm{n}}} w_{ij}$, $\mathrm{n} \in S$

2: find I_m, such that $I_m = \mathrm{argmin}_{n \in S} \, ||q_i - I_n||_2^2$

Ensure: I_m



Method

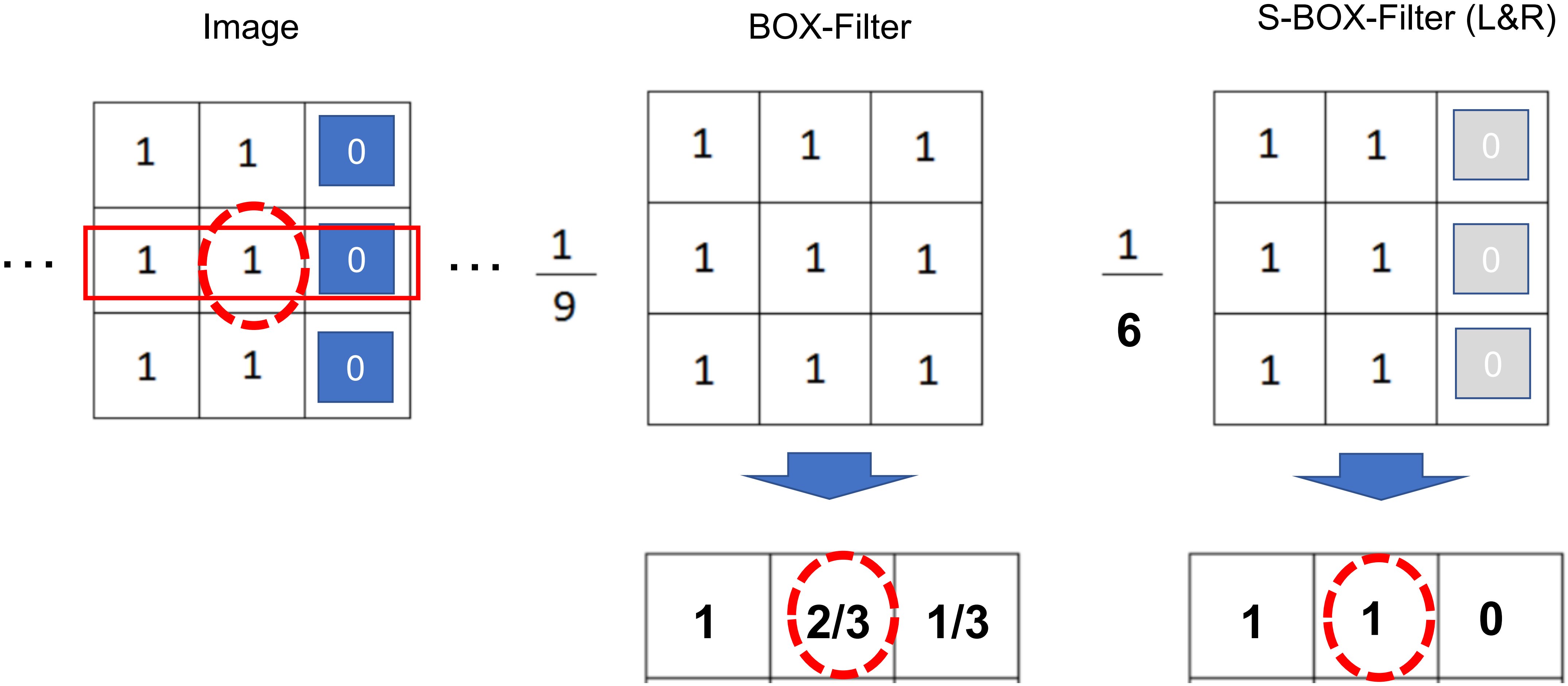


Image
BOX-Filter
S-BOX-Filter (L&R)
1 1 0
1 1 0
1 1 0
1/9
1 1 1
1 1 1
1 1 1
1 2/3 1/3
1/6
1 1 0
1 1 0
1 1 0
1 1 0

Method

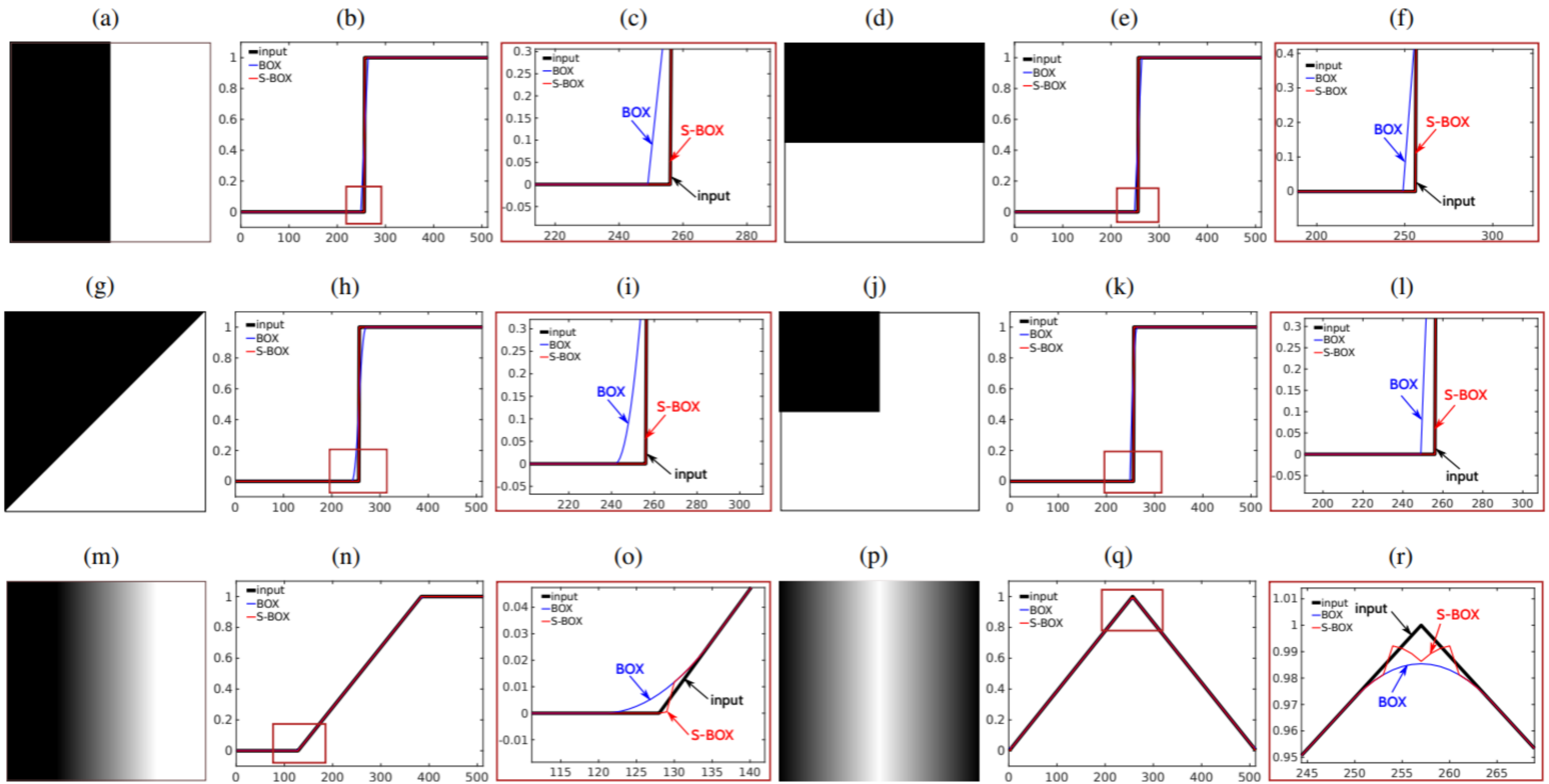


Figure 3. Comparing BOX and S-BOX on the testing images with different edges. The first and forth columns (a), (g), (m), (d), (j) and (p) are input images with edge or corner. The second and fifth columns are middle line profiles for input, BOX filter and S-BOX filter. The third and sixth columns are the zoomed in region at the edge or corner location.

Method

Table 2. Summary of the output of each side window in S-BOX

Case	L	R	U	D	NW	NE	SW	SE
(a)	$\mathbf{u}$	$\frac{u+rv}{r+1}$	$\frac{(r+1)u+rv}{2r+1}$	$\frac{(r+1)u+rv}{2r+1}$	$\mathbf{u}$	$\frac{u+rv}{r+1}$	$\mathbf{u}$	$\frac{u+rv}{r+1}$
(d)	$\frac{(r+1)u+rv}{2r+1}$	$\frac{(r+1)u+rv}{2r+1}$	$\mathbf{u}$	$\frac{u+rv}{r+1}$	$\mathbf{u}$	$\mathbf{u}$	$\frac{u+rv}{r+1}$	$\frac{u+rv}{r+1}$
(g)	$\frac{(\frac{3r}{2}+1)u+\frac{r}{2}v}{2r+1}$	$\frac{(\frac{r}{2}+1)u+\frac{3r}{2}v}{2r+1}$	$\frac{(\frac{3r}{2}+1)u+\frac{r}{2}v}{2r+1}$	$\frac{(\frac{r}{2}+1)u+\frac{3r}{2}v}{2r+1}$	$\mathbf{u}$	$\frac{(\frac{r}{2}+1)u+\frac{r}{2}v}{r+1}$	$\frac{(\frac{r}{2}+1)u+\frac{r}{2}v}{r+1}$	$\frac{((r+1)^2-1)v+u}{(r+1)^2}$
(j)	$\frac{(r+1)u+rv}{2r+1}$	$\frac{u+2rv}{2r+1}$	$\frac{(r+1)u+rv}{2r+1}$	$\frac{u+2rv}{2r+1}$	$\mathbf{u}$	$\frac{u+rv}{r+1}$	$\frac{u+rv}{r+1}$	$\frac{((r+1)^2-1)v+u}{(r+1)^2}$
(m)	$\mathbf{u}$	$u+\frac{r}{2}\Delta v$	$u+\frac{r(r+1)\Delta v}{2(2r+1)}$	$u+\frac{r(r+1)\Delta v}{2(2r+1)}$	$\mathbf{u}$	$\frac{u}{r+1}+\frac{r}{2}\Delta v$	$\mathbf{u}$	$\frac{u}{r+1}+\frac{r}{2}\Delta v$
(p)	$v-\frac{r}{2}\Delta u$	$v-\frac{r}{2}\Delta u$	$v-\frac{r(r+1)\Delta u}{2r+1}$	$v-\frac{r(r+1)\Delta u}{2r+1}$	$v-\frac{r}{2}\Delta u$	$v-\frac{r}{2}\Delta u$	$v-\frac{r}{2}\Delta u$	$v-\frac{r}{2}\Delta u$

Experiments

Popular Filters under the SWF Framework

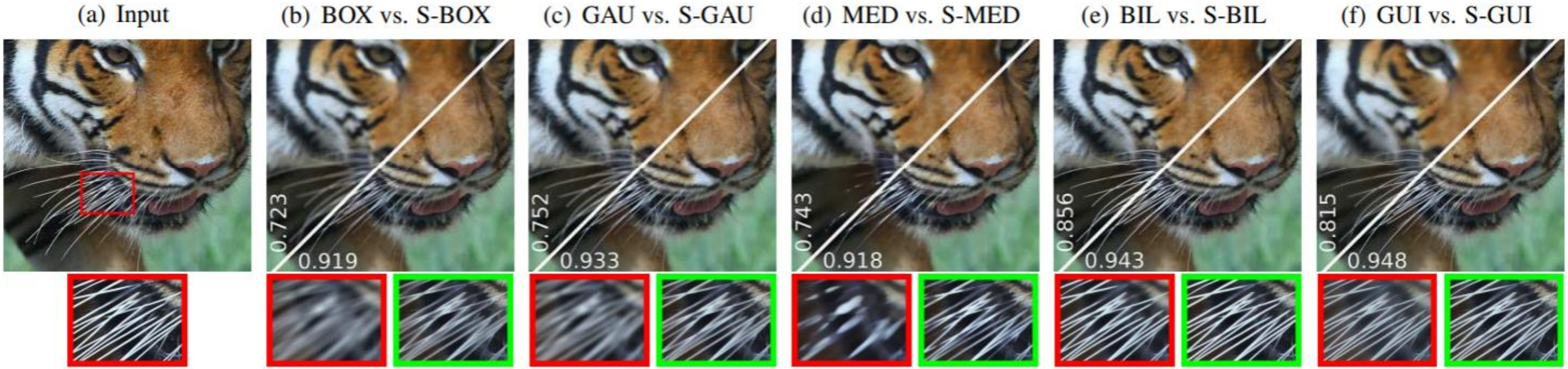


Figure 4. Image smoothing ($r = 7$, $\sigma = 4$ for GAU and S-GAU, $\sigma_s = 7$, $\sigma_r = 0.3$ for BIL and S-BIL, $\epsilon = 0.1$ for GUI and S-GUI). The upper left part of each result is from the traditional filter and the zoomed in patch is with red rectangle. The lower right part of each result is from the side window version and the zoomed in patch is with green rectangle. The number shown on each image is the SSIM[27] value.

Experiments

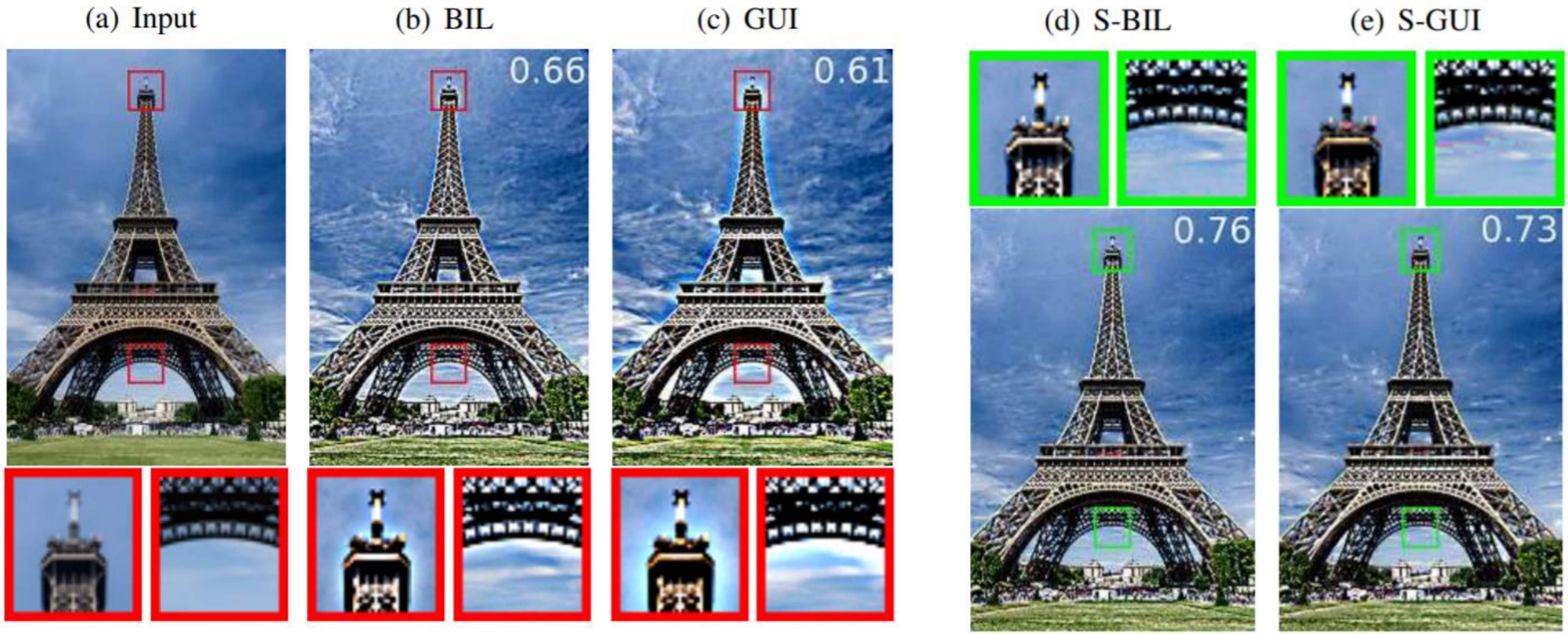
Image denoising

Figure 5. Image denoising ($r = 10, \sigma = 5$ for GAU and S-GAU, $\sigma_s = 10, \sigma_r = 0.3$ for BIL and S-BIL, $\epsilon = 0.1$ for GUI and S-GUI, $iteration = 5$). The left part of each result is from the traditional filter and the zoomed in patch is with red rectangle. The right part of each result is from the side window version and the zoomed in patch is with green rectangle. The number shown on each image is PSNR.

Experiments

Image enhancement

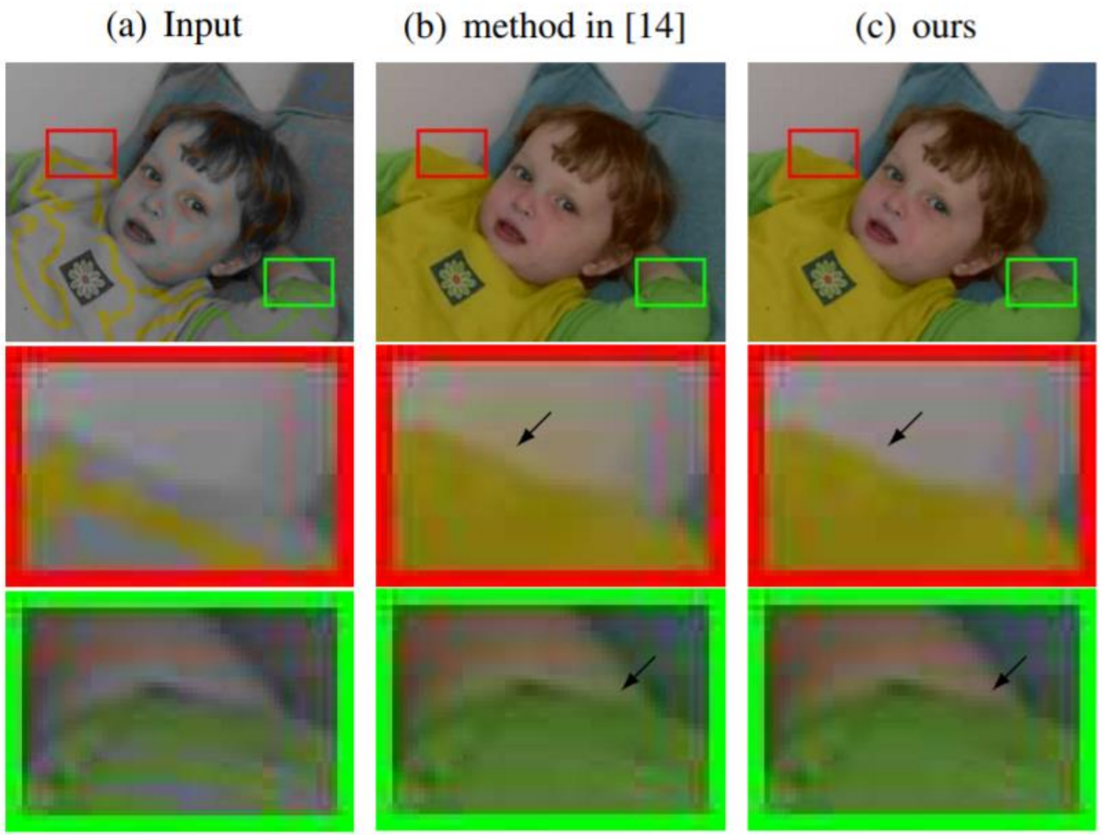
$$Enhanced = q + \alpha \times (q - I^{'})$$



Experiments

Colorization by optimization

$$J(U) = \sum_i \left(U(i) - \sum_{j \in N(i)} \omega_{ij} U(j) \right)^2$$



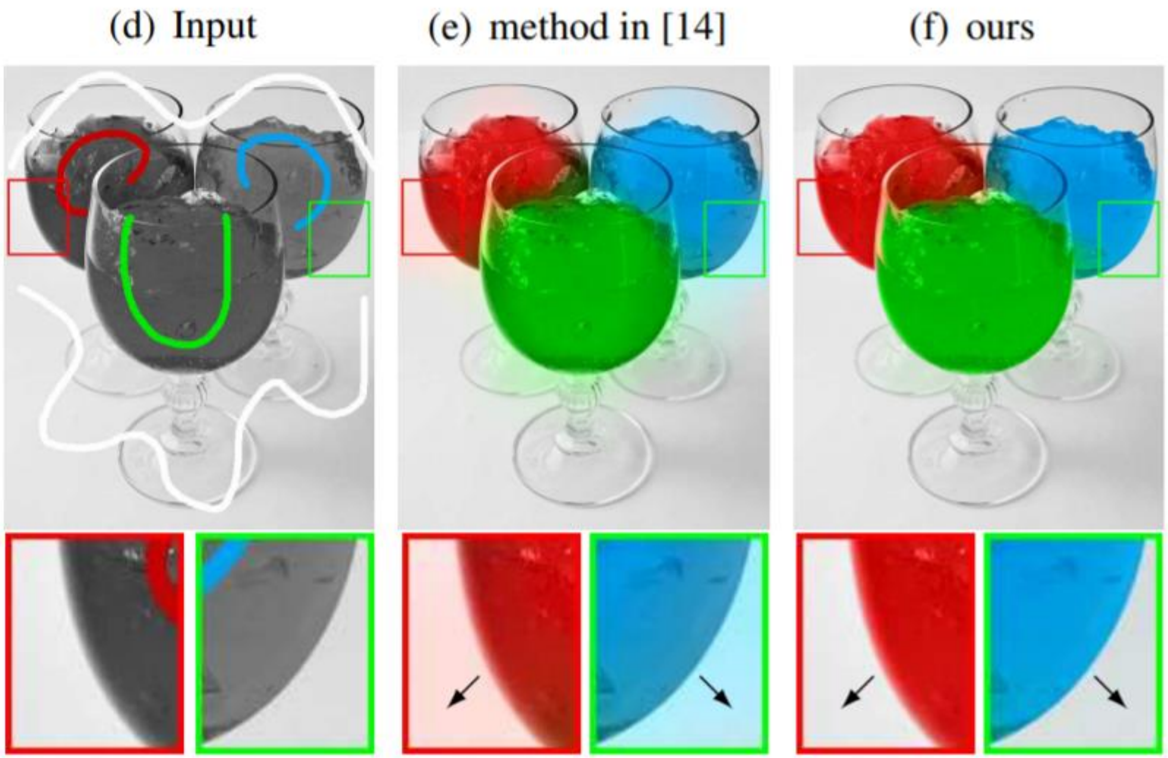


Figure 10. Colorization ($r = 3$). Color leakage existed in the original method is avoided by implementing the method under the SWF framework.

Thank you