Propagated Image Filtering

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Image Filtering

- Image processing tasks such as denoising, smoothing, and fusion with image context properly preserved.
- Edge-preserving filters
  - Avoid blending the characteristics of adjacent image regions.

Original image | Without edge-preserving | With edge-preserving

Related Work

- General formulation for image filtering

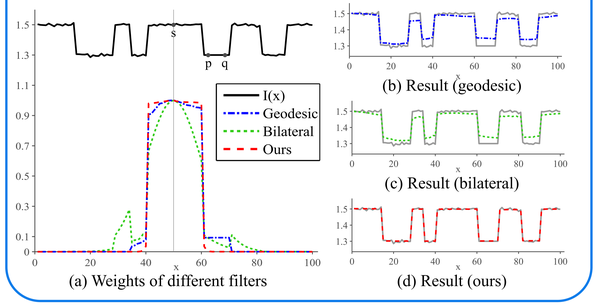
$$I'_s \leftarrow \frac{1}{Z}\sum_{t\in\mathcal{N}(s)} w_{s,t}\, I_t,\ Z=\sum_{t\in\mathcal{N}(s)} w_{s,t},\ \mathcal{N}(s):\text{neighbors of } s$$

- Bilateral filter

$$w_{s,t}=g(\|s-t\|;\sigma_s)\, g(\|I_s-I_t\|;\sigma_r),\ g(x;\sigma)=e^{\frac{-x^2}{2\sigma^2}}$$

- Geodesic filter

$$w_{s,t}=g_r\left(\sum_{x,x+1\in s,\ldots,t}\|I_x-I_{x+1}\|\right)$$

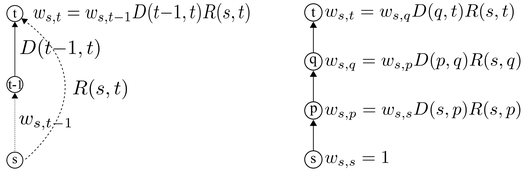


(a) Weights of different filters

(b) Result (geodesic) (c) Result (bilateral) (d) Result (ours)

Propagation Filter

- **Main idea**:
  - Filter weight $w_{s,t}$ as the probability of pixel t related to s.
- **Definition in 1D (by Bayes' rule)**:



$$w_{s,t} := P(s\to t) = P\left(s\to t-1\ \wedge\ t-1\xrightarrow{a} t\ \wedge\ s\xrightarrow{r} t\right)$$

$$= P(s\to t-1)\ P\left(t-1\xrightarrow{a} t\ \wedge\ s\xrightarrow{r} t \mid s\to t-1\right)$$

$$= w_{s,t-1}\ P\left(t-1\xrightarrow{a} t \mid s\to t-1\right) P\left(s\xrightarrow{r} t \mid s\to t-1\wedge t-1\xrightarrow{a} t\right)$$

$$:= w_{s,t-1}\ D(t-1,t)\ \ R(s,t)$$

adjacent photometric relationship | photometric relationship

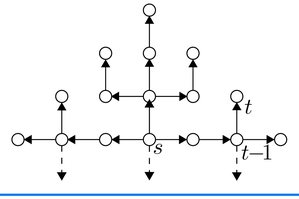
  - In other words,

$$t \text{ related to } s := (t-1 \text{ related to } s)\wedge(I_t\approx I_{t-1})\wedge(I_t\approx I_s)$$

  - For simplicity, we have

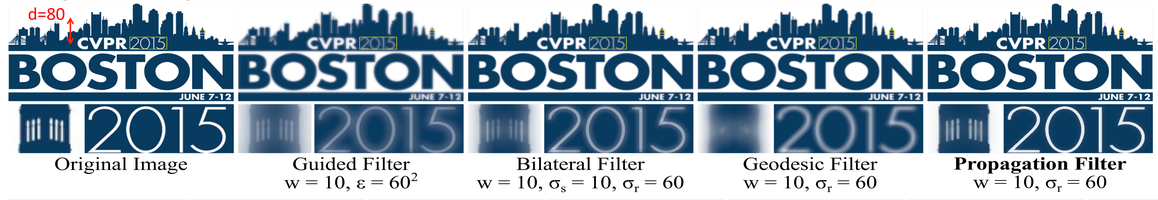
$$D(x,y)=R(x,y)=g(\|I_x-I_y\|;\sigma_r)$$

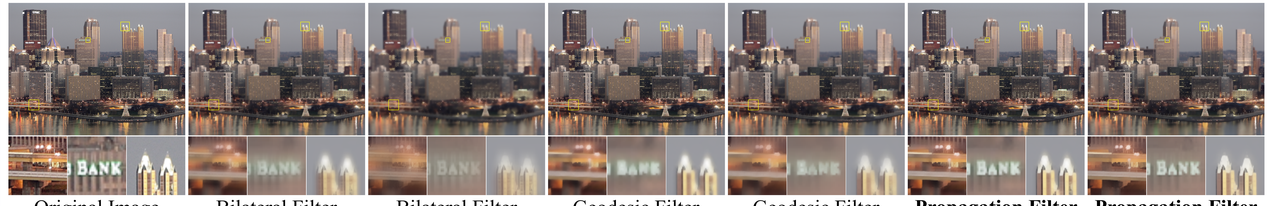
- **For filtering in 2D (i.e., images)**:
  - Use predefined filtering patterns (see below) instead of determining the shortest path between pixels s and t.
  - Filter weights can be reused (i.e., *propagated*).
  - Parallel processing and early termination for speedup.
- **Theoretical supports**:
  - Robust estimation
  - Belief propagation



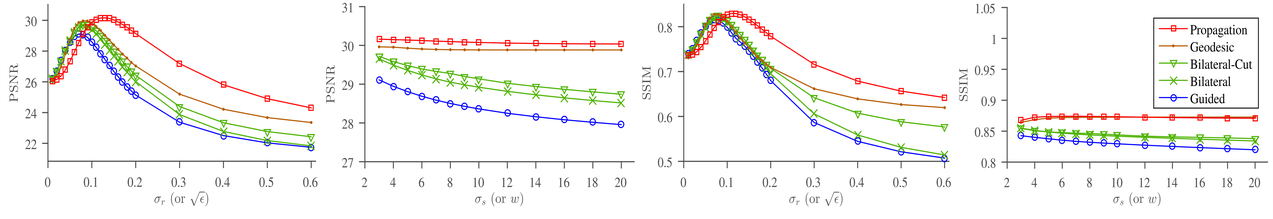
Applications

- Image smoothing





- Image denoising: images with Gaussian white noise (σ=0.05)



- Flash / no-flash image denoising