Tone mapping

Digital Visual Effects, Spring 2006

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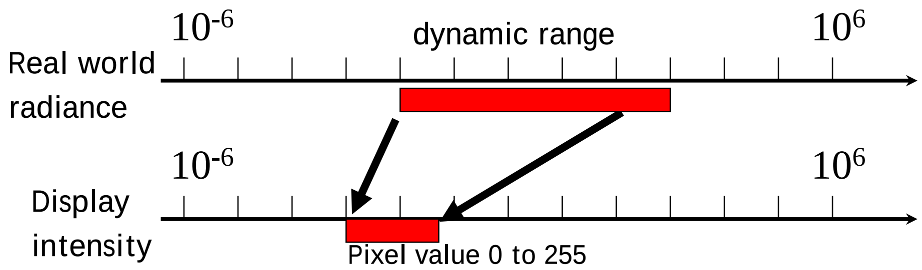
with slides by Fredo Durand, and Alexei Efros

Tone mapping

- How can we display it?
  Linear scaling?, thresholding?



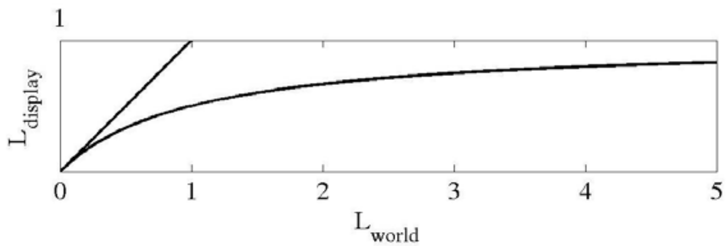
CRT has 300:1 dynamic range

Global operator (Reinhart et al)

$$\bar{L} = \exp\left(\frac{1}{N}\sum_{x,y}\log(\delta + L(x,y))\right)$$

$$L_w(x,y) = \frac{a}{\bar{L}} L(x,y)$$

$$L_{display} = \frac{L_{world}}{1+L_{world}}$$



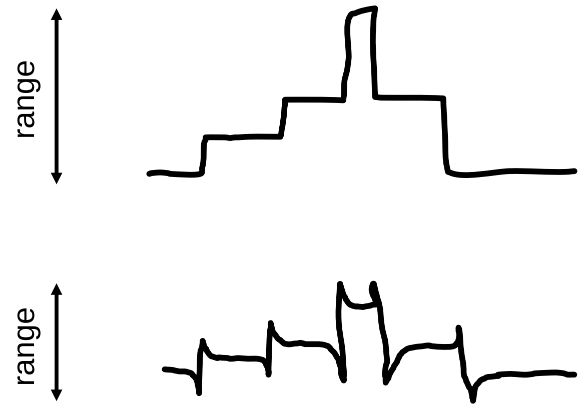
Global operator results

Eye is not a photometer!

- *"Every light is a shade, compared to the higher lights, till you come to the sun; and every shade is a light, compared to the deeper shades, till you come to the night."*

  — John Ruskin, 1879

Compressing dynamic range



Fast Bilateral Filtering for the Display of High-Dynamic-Range Images

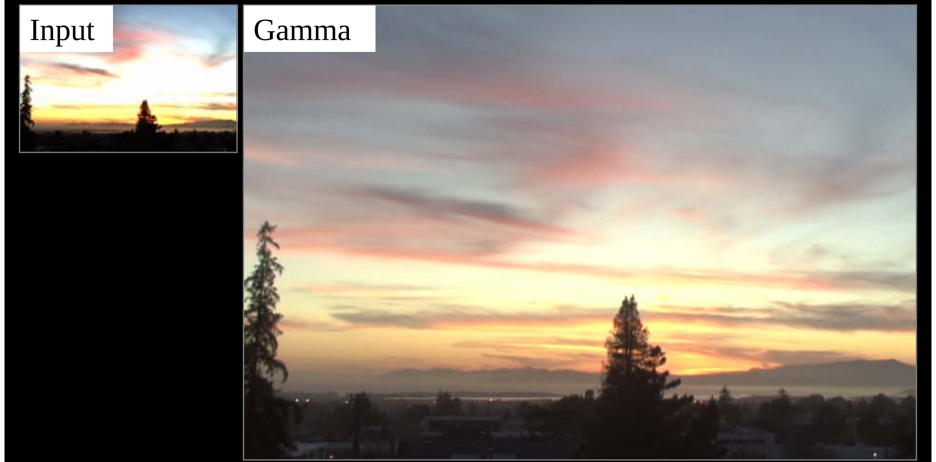
Frédo Durand & Julie Dorsey
Laboratory for Computer Science
Massachusetts Institute of Technology

A typical photo

- Sun is overexposed
- Foreground is underexposed

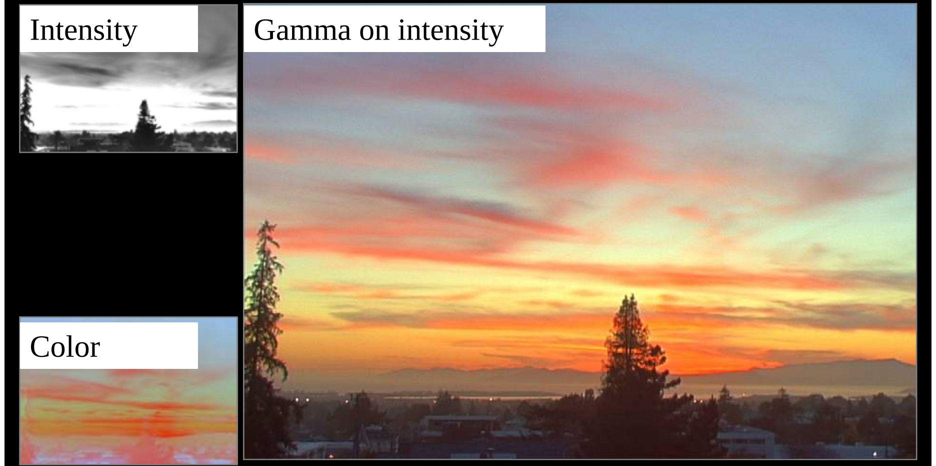
Gamma compression

- X –> X^{γ}
- Colors are washed-out



Gamma compression on intensity

- Colors are OK, but details (intensity high-frequency) are blurred

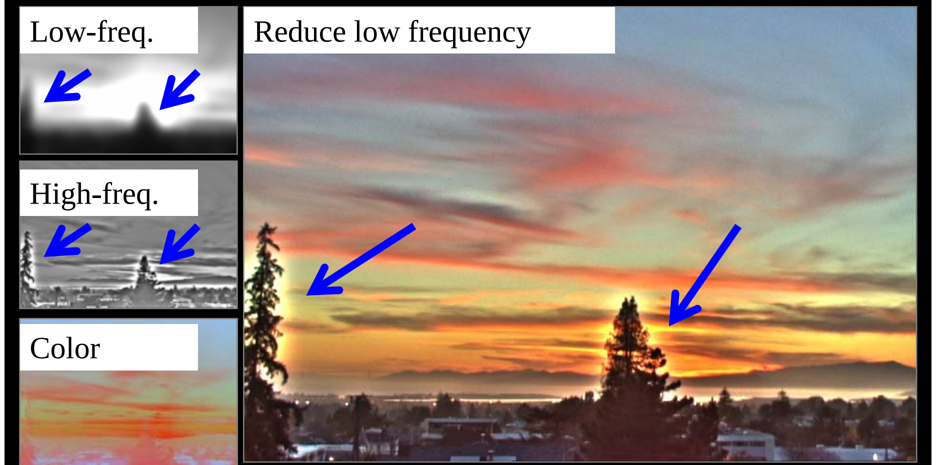


Chiu et al. 1993

- Reduce contrast of low-frequencies
- Keep high frequencies

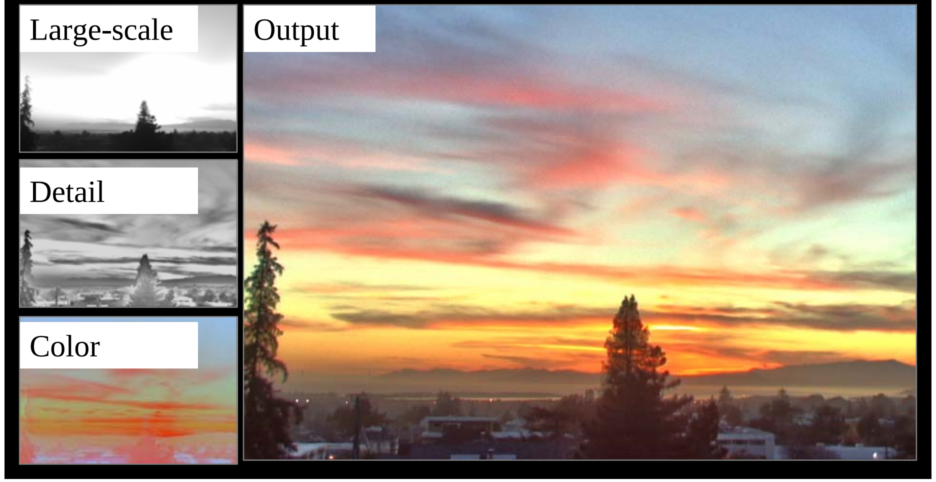
The halo nightmare

- For strong edges
- Because they contain high frequency



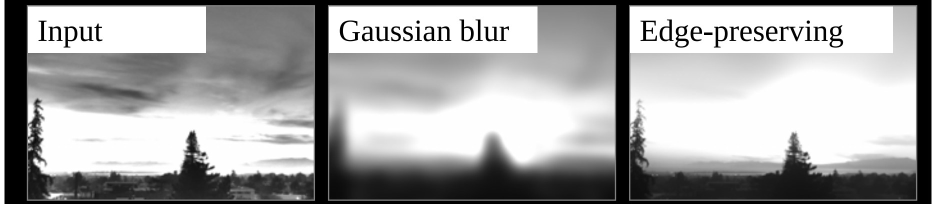
Durand and Dorsey

- Do not blur across edges
- Non-linear filtering



Edge-preserving filtering

- Blur, but not across edges

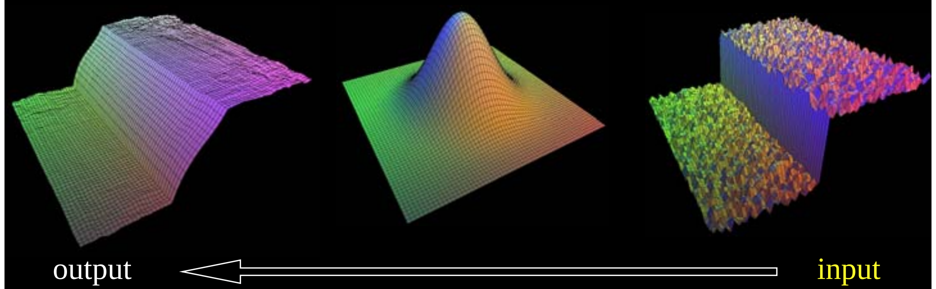


- Anisotropic diffusion [Perona & Malik 90]
  - Blurring as heat flow
  - LCIS [Tumblin & Turk]
- Bilateral filtering [Tomasi & Manduci, 98]

Start with Gaussian filtering

- Here, input is a step function + noise

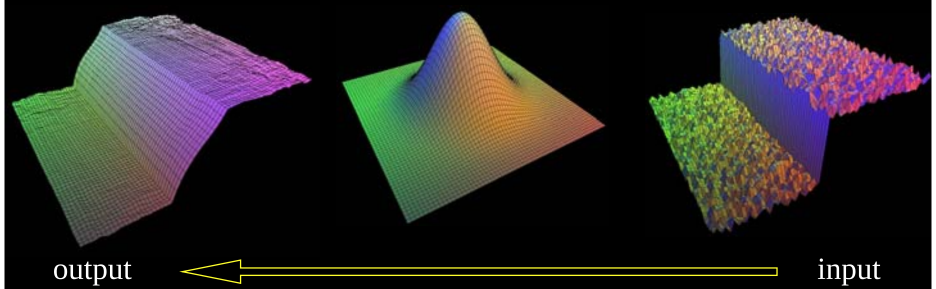
$$J = f \otimes I$$



Start with Gaussian filtering

- Spatial Gaussian f

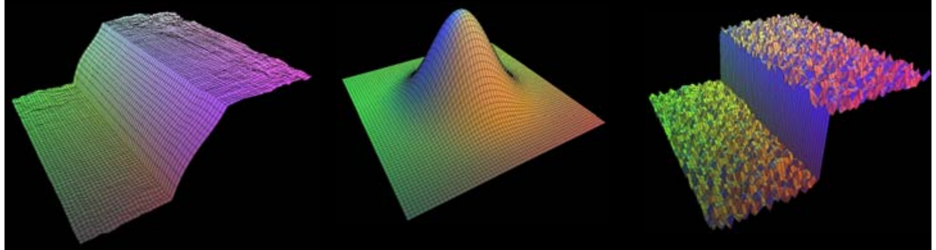
$$J = f \otimes I$$



Start with Gaussian filtering

- Output is blurred

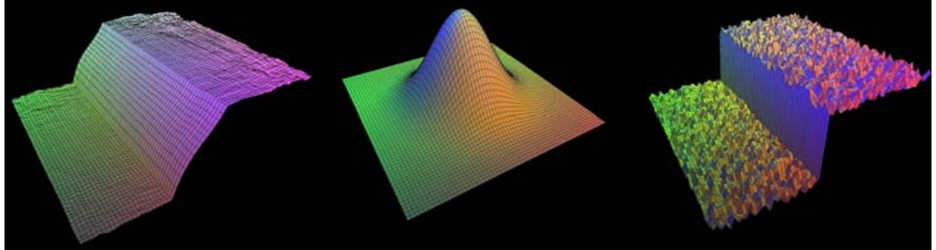
$$J = f \otimes I$$



output ⟵ input

Gaussian filter as weighted average

$$J(x) = \sum_{\xi} f(x,\xi) \; I(\xi)$$

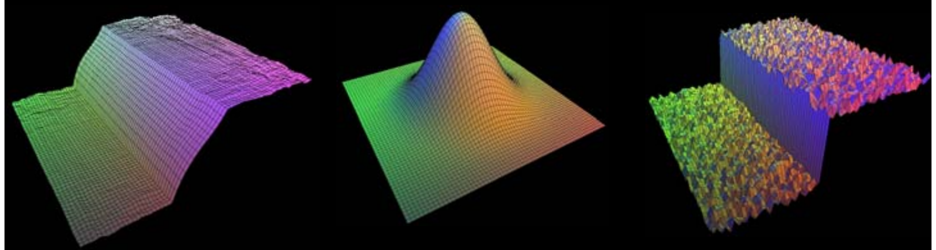


output ⟵ input

The problem of edges

- Here, $I(\xi)$ "pollutes" our estimate J(x)
- It is too different

$$J(x) = \sum_{\xi} f(x,\xi) \; I(\xi)$$

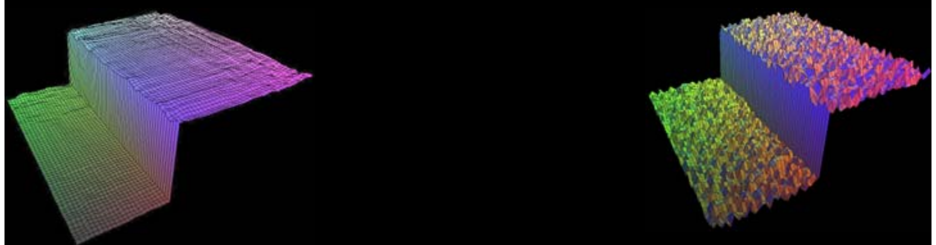


output ⟵ input

Principle of Bilateral filtering

- [Tomasi and Manduchi 1998]
- Penalty g on the intensity difference

$$J(x) = \frac{1}{k(x)} \sum_{\xi} f(x,\xi) \; g(I(\xi) - I(x)) \; I(\xi)$$

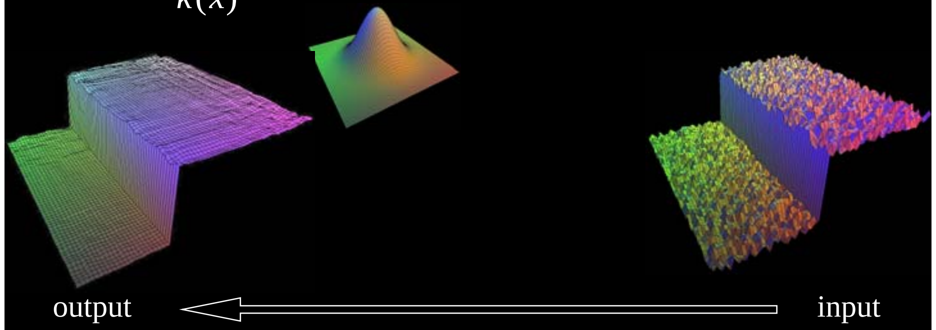


output ⟵ input

Bilateral filtering

- [Tomasi and Manduchi 1998]
- Spatial Gaussian f

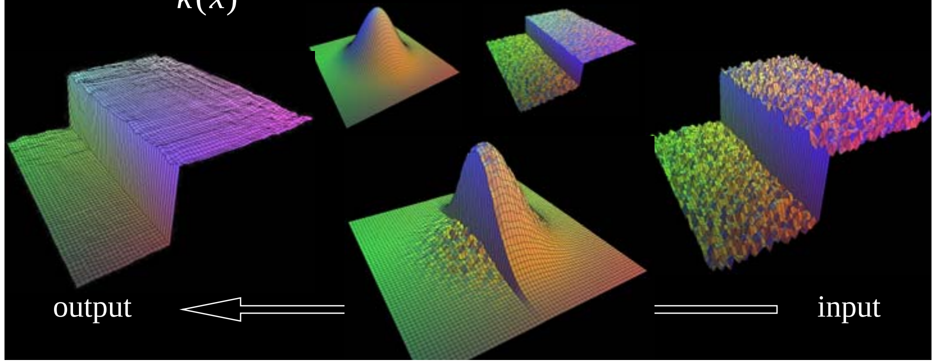
$$J(x) \quad \frac{1}{k(x)} \quad f(x,\xi) \quad g(I(\xi)-I(x)) \quad I(\xi)$$



Bilateral filtering

- [Tomasi and Manduchi 1998]
- Spatial Gaussian f
- Gaussian g on the intensity difference

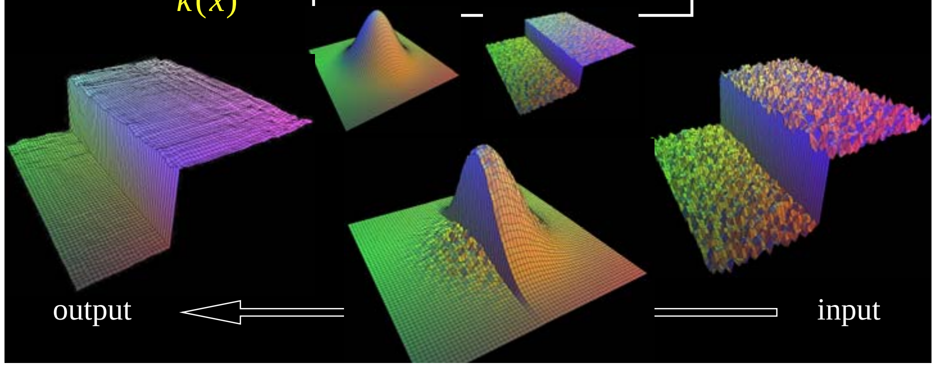
$$J(x) \quad \frac{1}{k(x)} \quad f(x,\xi) \quad g(I(\xi)-I(x)) \quad I(\xi)$$



Normalization factor

- [Tomasi and Manduchi 1998]
- k(x)= $\sum_{\xi} f(x,\xi) \quad g(I(\xi)-I(x))$

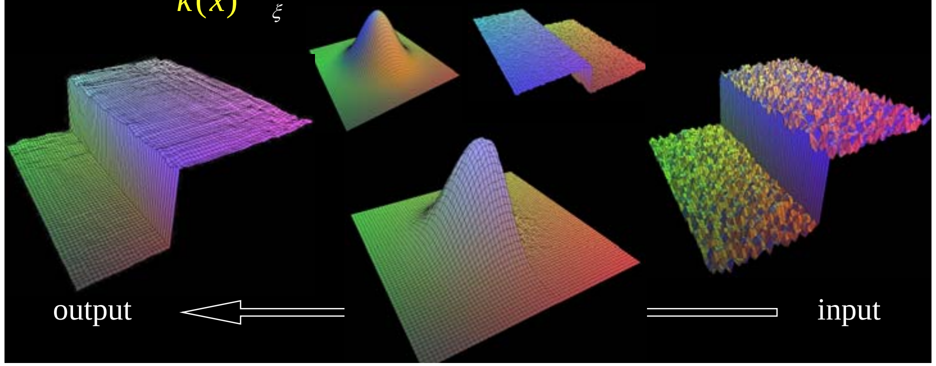
$$J(x) \quad \frac{1}{k(x)} \quad f(x,\xi) \quad g(I(\xi)-I(x)) \quad I(\xi)$$



Bilateral filtering is non-linear

- [Tomasi and Manduchi 1998]
- The weights are different for each output pixel

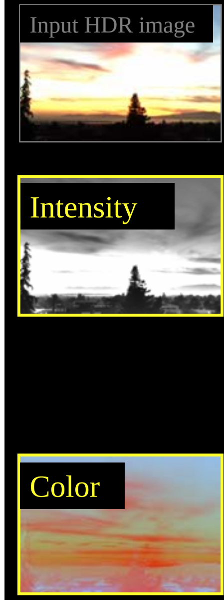
$$J(x) \quad \frac{1}{k(x)} \sum_{\xi} f(x,\xi) \quad g(I(\xi)-I(x)) \quad I(\xi)$$



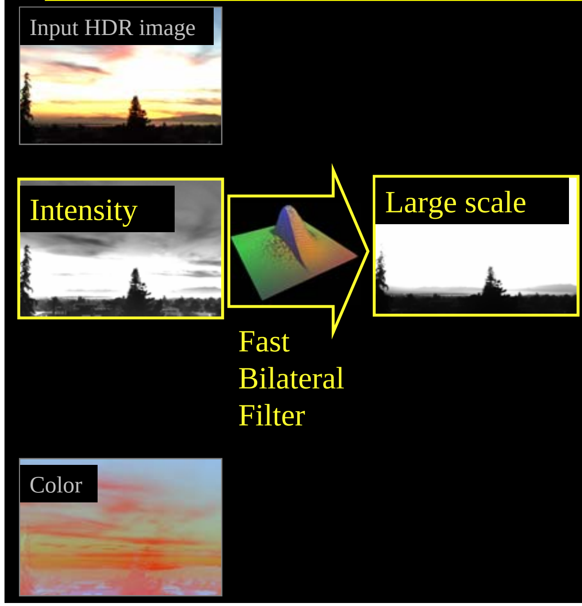
Contrast reduction

Contrast
too high!

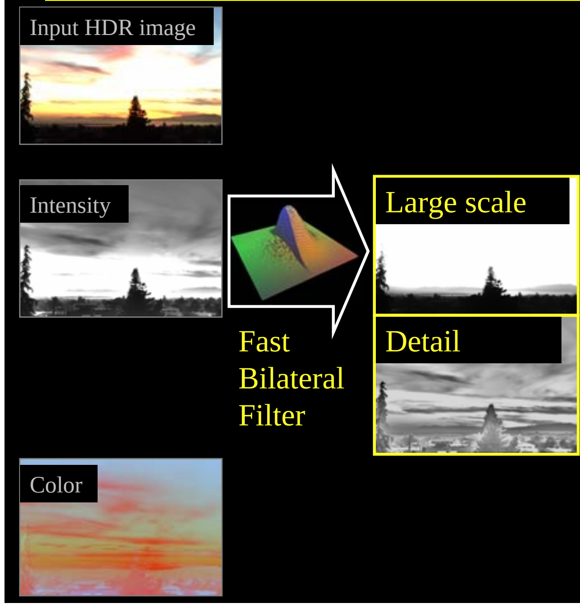
Contrast reduction

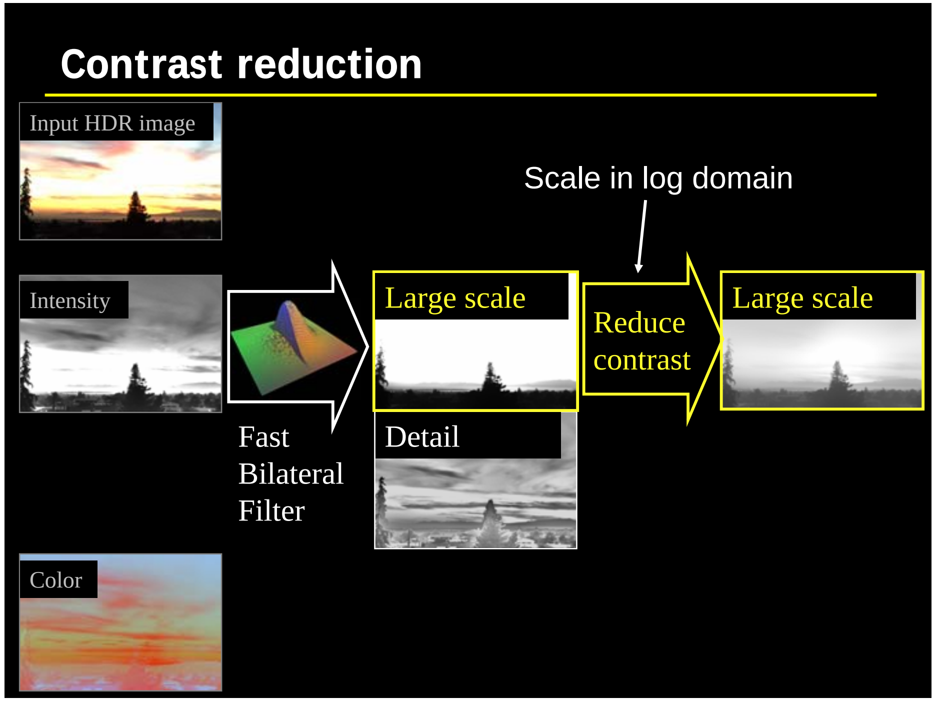


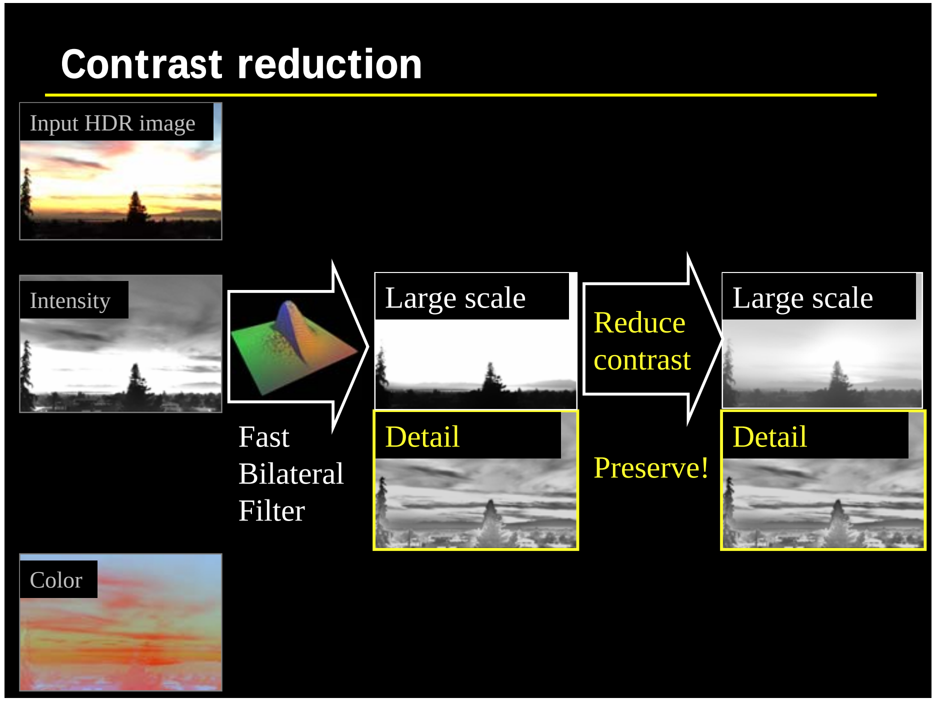
Contrast reduction

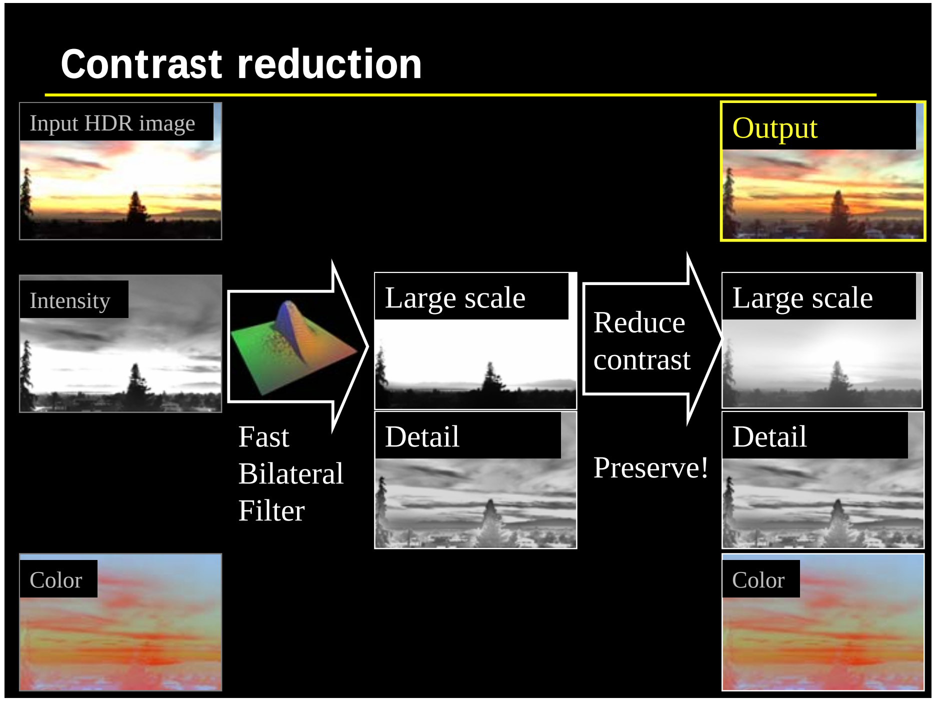


Contrast reduction




Contrast reduction
Input HDR image
Scale in log domain
Intensity
Large scale
Reduce contrast
Large scale
Fast Bilateral Filter
Detail
Color


Contrast reduction
Input HDR image
Intensity
Large scale
Reduce contrast
Large scale
Fast Bilateral Filter
Detail
Preserve!
Detail
Color


Contrast reduction
Input HDR image
Output
Intensity
Large scale
Reduce contrast
Large scale
Fast Bilateral Filter
Detail
Preserve!
Detail
Color
Color