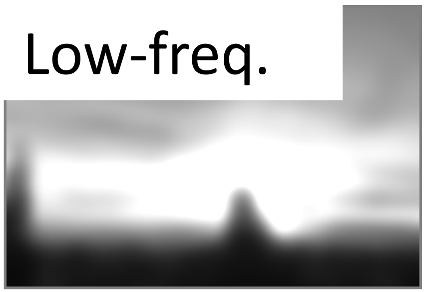
Bilateral Filtering for Tone Mapping

Chiu et al. 1993

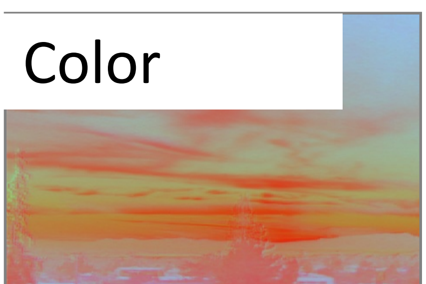
- Reduce contrast of low-frequencies
- Keep high frequencies

Low-freq.



High-freq.

Color

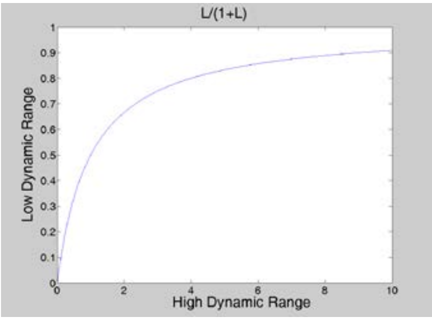


Reduce low frequency

How Does It Work?

- Local tone mapping function

$$L = H \times V \qquad \varphi(x) = \frac{x}{1+x}$$



compress it by the global mapping function

$$L' = H \times V'$$

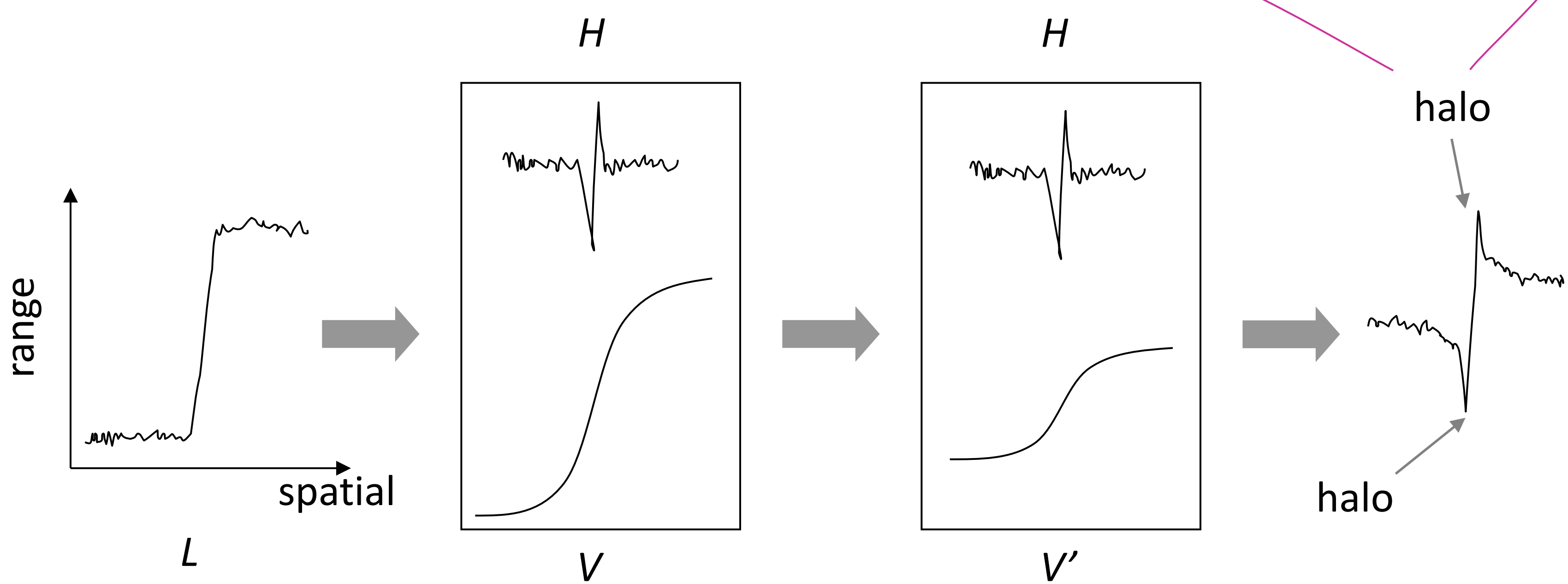
$$= \left(\frac{L}{V}\right) \times \left(\frac{V}{1+V}\right) = \boxed{\frac{L}{1+V}}$$

spatial varying

local mapping function

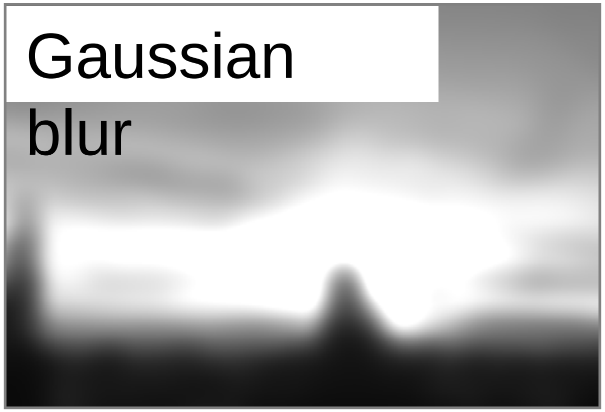
Halos

- Inverse contrasts/gradients



Preventing Halos

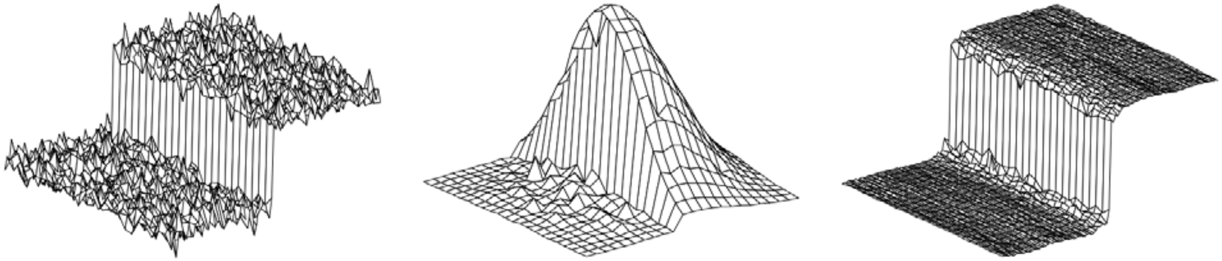
- Need to construct a more appropriate local adaptation luminance V
- Local averaging without blurring edges
  - Multi-scale center-surround



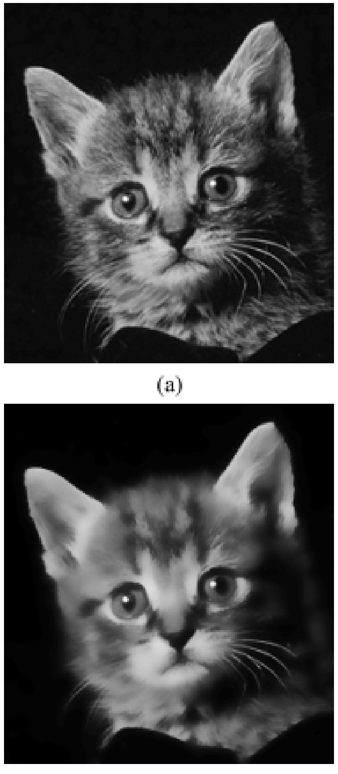
Bilateral Filtering

- [Bilateral Filtering for Gray and Color Images](), Tomasi and Manduchi
  - ICCV 1998

$$J(s) = \frac{1}{k(s)} \sum_{p \in \Omega} f(p-s)\, g(I_p^t - I_s^t)\, I_p^t$$



(a) (b) (c)

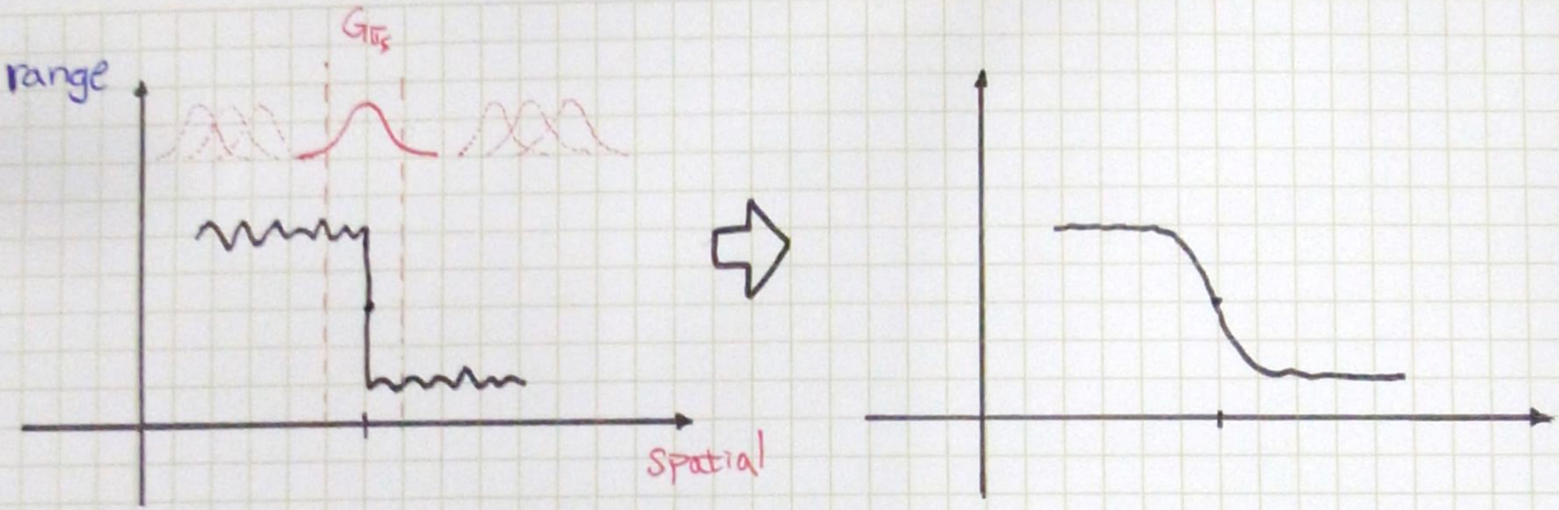


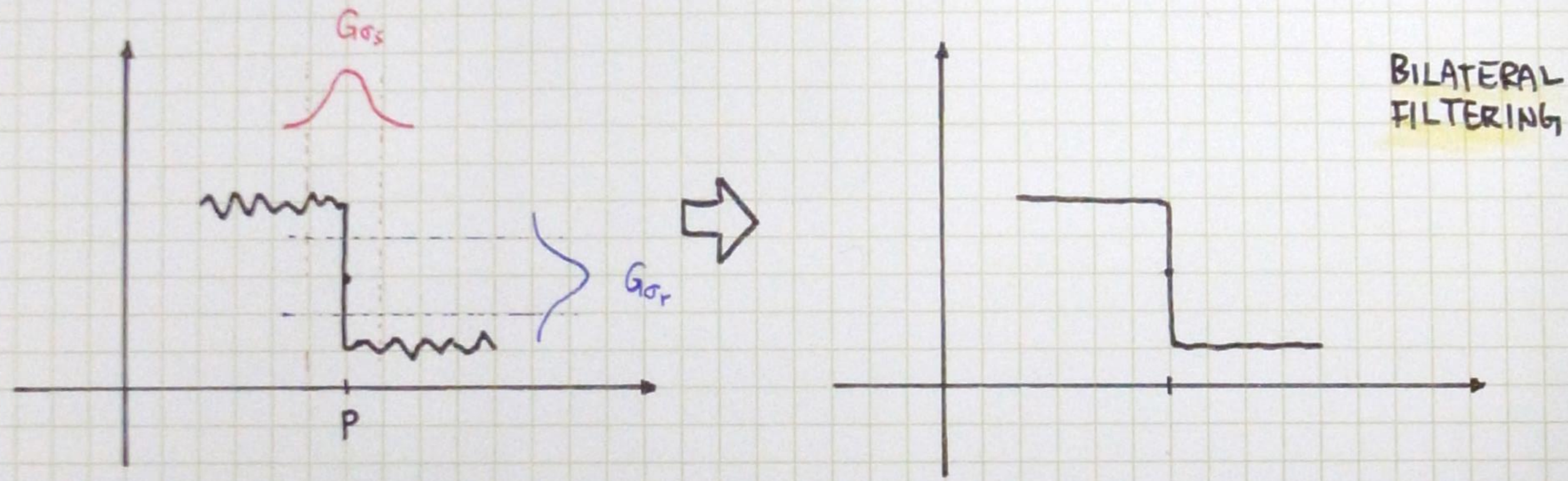
(a)

(b)

DATE/NO. TITLE

BILATERAL FILTERING & JOINT BILATERAL FILTERING





- *Fast Bilateral Filtering for the Display of High-Dynamic-Range Images*
  - F. Durand's ppt slides

Acceleration

$$
\begin{aligned}
J_s^j &= \frac{1}{k^j(s)} \sum_{p \in \Omega} f(p-s) \quad g(I_p - i^j) \;\; I_p \\
&= \frac{1}{k^j(s)} \sum_{p \in \Omega} f(p-s) \quad H_p^j
\end{aligned}
$$

$$
\begin{aligned}
k^j(s) &= \sum_{p \in \Omega} f(p-s) \;\; g(I_p - i^j) \\
&= \sum_{p \in \Omega} f(p-s) \;\; G^j(p).
\end{aligned}
$$


SATURDAY
MAY
19TH
STARTING AT
11:00 AM
FREE
WITH
STEVE
VAI
AUTOGRAPH SESSION
SEE THE NEW
JEM20TH
LIGHT UP!

PiecewiseBilateral

(Image I, spatial kernel f_{σ_s}, intensity influence g_{σ_r})

J=0 /* *set the output to zero* */

for j=0..NB_SEGMENTS

i^j= minI+j × (max(I)-min(I))/NB_SEGMENTS

G^j=g_{σ_r} (I - i^j) /* evaluate g_{σ_r} at each pixel */

K^j=$G^j \otimes f_{\sigma_s}$ /* normalization factor */

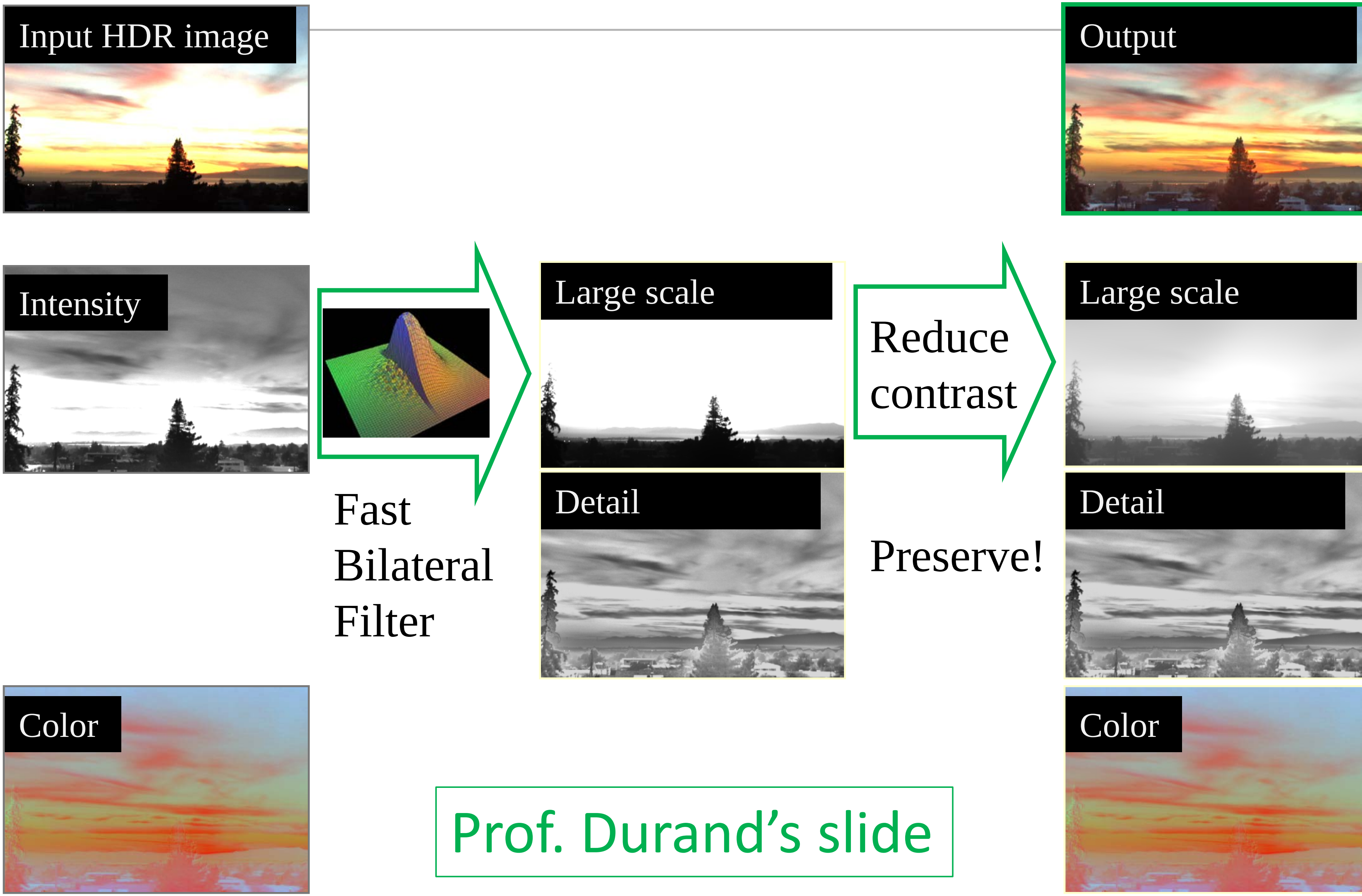
H^j=G^j × I /* compute H for each pixel */

H^{*j}=$H^j \otimes f_{\sigma_s}$

J^j=H^{*j}/K^j /* normalize */

J=J+J^j × InterpolationWeight(I, i^j)

Contrast reduction



Anisotropic Diffusion

- Heat propagation

$$\frac{\partial I}{\partial t} = \text{div}\,[g(\|\nabla I\|)\nabla I] \qquad \text{for edge stoping, } g = ?$$

- Perona & Malik

$$g_1(x) = \frac{1}{1 + \frac{x^2}{\sigma^2}} \qquad g_2(x) = e^{-x^2/\sigma^2}$$

a large ∇I means a small g

- Discrete version $I_s^{t+1} = I_s^t + \frac{\lambda}{4} \sum_{p \in N_4(s)} g(I_p^t - I_s^t)\,(I_p^t - I_s^t)$

Robust Anisotropic Diffusion

- Robust to outliers
  - Black et al.

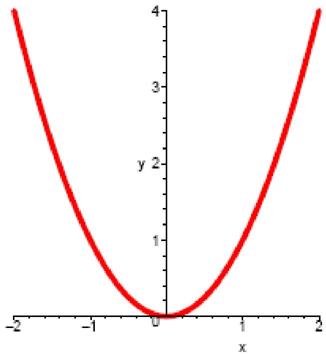
$$\text{minimize} \sum_{s\in\Omega} \sum_{p\in N_4(s)} \rho(I_p^t - I_s^t)$$

minimize error
over the whole image

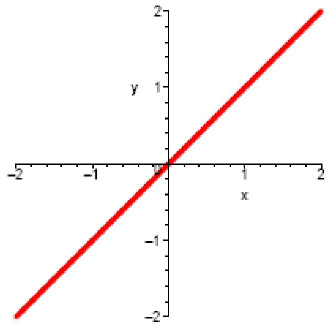
$$I_s^{t+1} = I_s^t + \frac{\lambda}{4} \sum_{p\in N_4(s)} \Psi(I_p^t - I_s^t)$$

$$\text{the influence } \Psi(x) = \rho'(x)$$

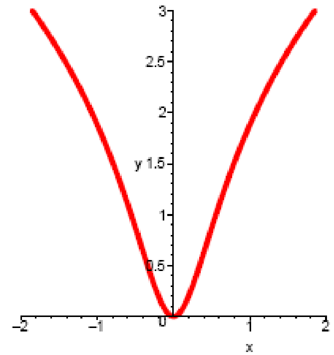
$$\text{Perona \& Malik } \Psi(\nabla I) = g(\nabla I)\nabla I$$



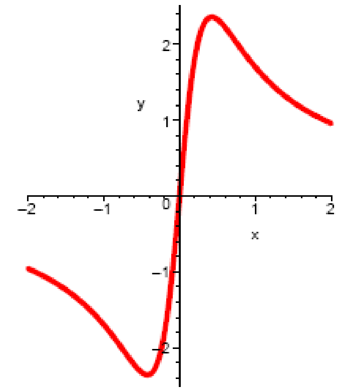
Least square $\rho(x)$



$\psi(x)$

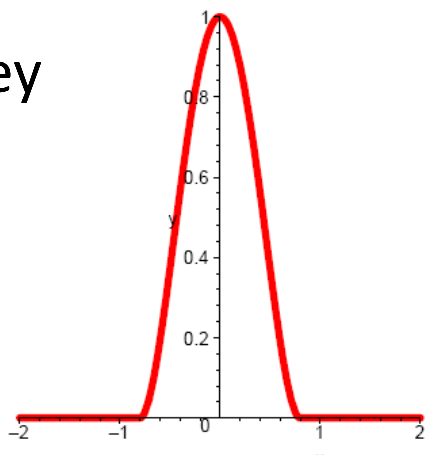


Lorentz $\rho(x)$

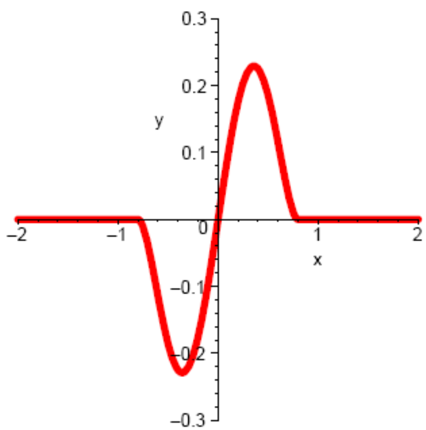


$\psi(x)$

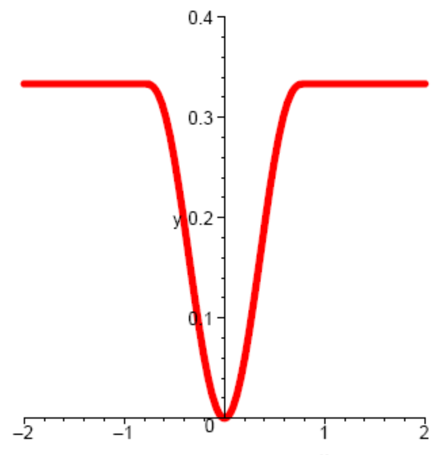
Tuckey



$g(x)$



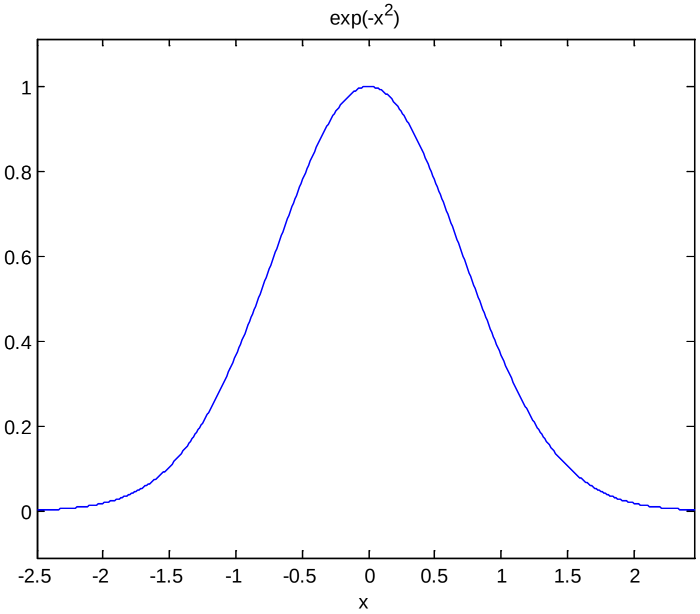
$\psi(x)$



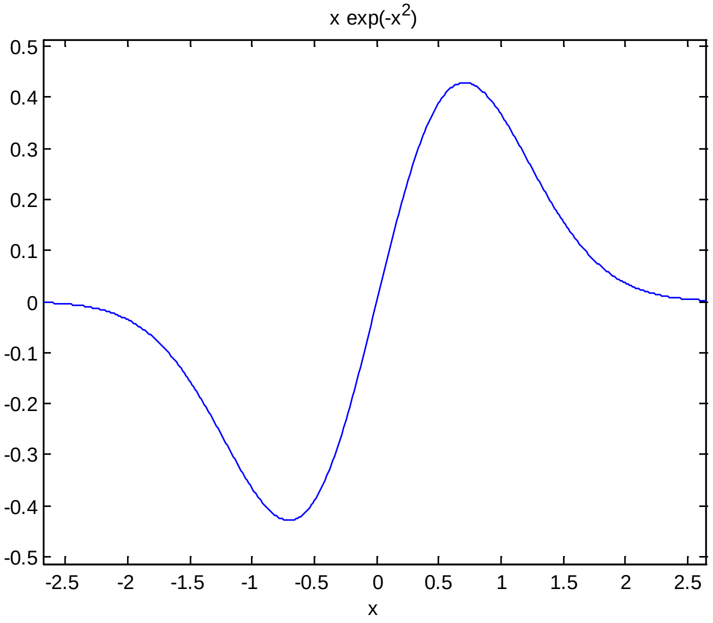
$\rho(x)$

Gaussian

$$g(x)$$



$$\Psi(x)$$



$$\Psi(x) = x\, g(x)$$

Huber	Lorentz
$g_\sigma(x) = \begin{cases} \frac{1}{\sigma} & \lvert x\rvert \le \sigma \\ \frac{1}{\lvert x\rvert}, & \text{otherwise} \end{cases}$	$g_\sigma(x) = \frac{2}{2+\frac{x^2}{\sigma^2}}$
σ	$\sigma/\sqrt{2}$
Tukey	**Gauss**
$g_\sigma(x) = \begin{cases} \frac{1}{2}[1-(x/\sigma)^2]^2 & \lvert x\rvert \le \sigma \\ 0, & \text{otherwise} \end{cases}$	$g_\sigma(x) = e^{-\frac{x^2}{2\sigma^2}}$
$\sigma * \sqrt{5}$	σ

Extend the 0-Oder Anisotropic Diffusion to a Larger Support

$$I_s^{t+1} = I_s^t + \frac{\lambda}{4} \sum_{p \in N_4(s)} g(I_p^t - I_s^t)\,(I_p^t - I_s^t)$$

$$\Downarrow$$

$$I_s^{t+1} = I_s^t + \frac{\lambda}{4} \sum_{p \in \Omega} f(p-s)\, g(I_p^t - I_s^t)\,(I_p^t - I_s^t)$$

- Energy preserving
  - Symmetric

Bilateral Filtering

- Non-iterative

$$J(s) = \frac{1}{k(s)} \sum_{p \in \Omega} f(p-s)\, g(I_p^t - I_s^t)\, I_p^t$$

- Not energy preserving

$k(s)$ differs

Related Work on Bilateral Filtering

- BILATERAL FILTERING: PAPERS, RESOURCES, APPLICATIONS, PARIS AND DURAND
- CONSTANT TIME O(1) BILATERAL FILTERING PORIKLI
  - CVPR 2008
- REAL-TIME O(1) BILATERAL FILTERING, YANG, TAN AND AHUJA
  - CVPR 2009
- SVM FOR EDGE-PRESERVING FILTERING, YANG, WANG AND AHUJA
  - CVPR 2010
- Image Smoothing via L0 Gradient Minimization, XU, LU, XU, AND JIA
  - SIGGRAPH Asia 2011.