SIGGRAPH ASIA 2015 KOBE

Real-time noise-aware tone mapping

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Video tone mapping Applications

Viewfinders

Display adaptation

In-camera processing stacks

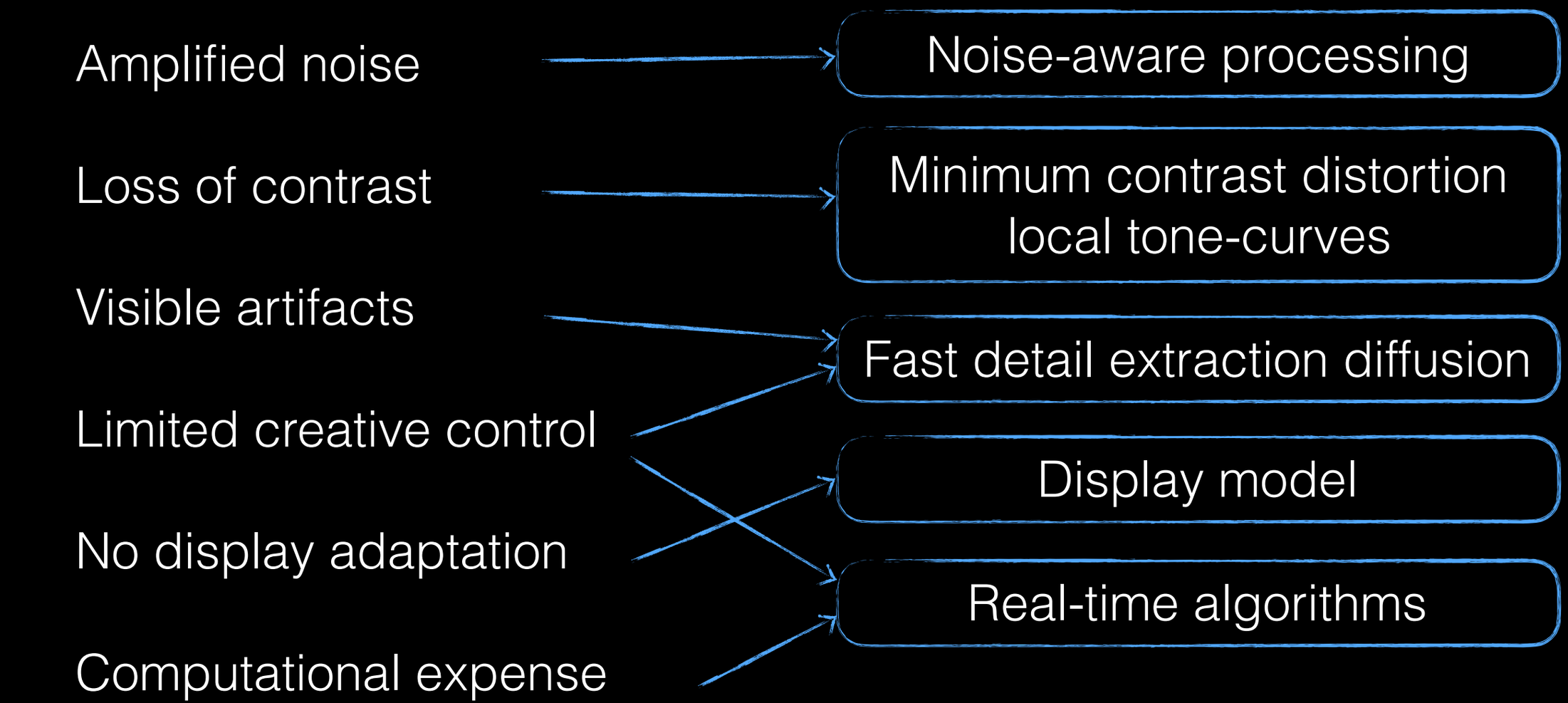
Video games

Video post processing

etc.

Video tone mapping

Problems with previous methods




Edge pres. filter: Bilateral filter
Tone-curve: Sigmoid S-curve

Filtering for tone mapping

Problem statement

Filter purpose

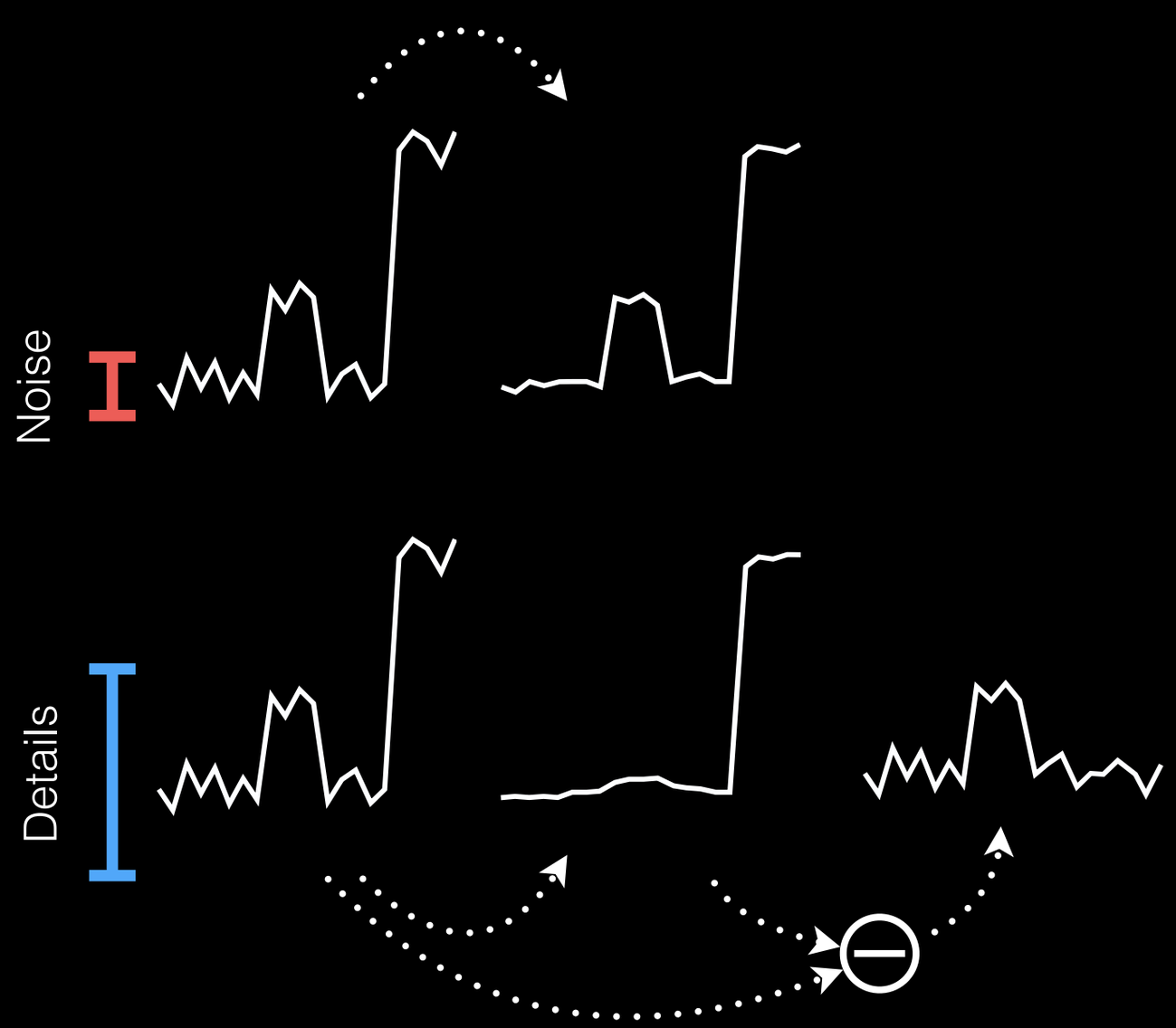
- Noise reduction, etc.
- Tone mapping is different

Detail extraction

- Large scale
- Different intent

Problems

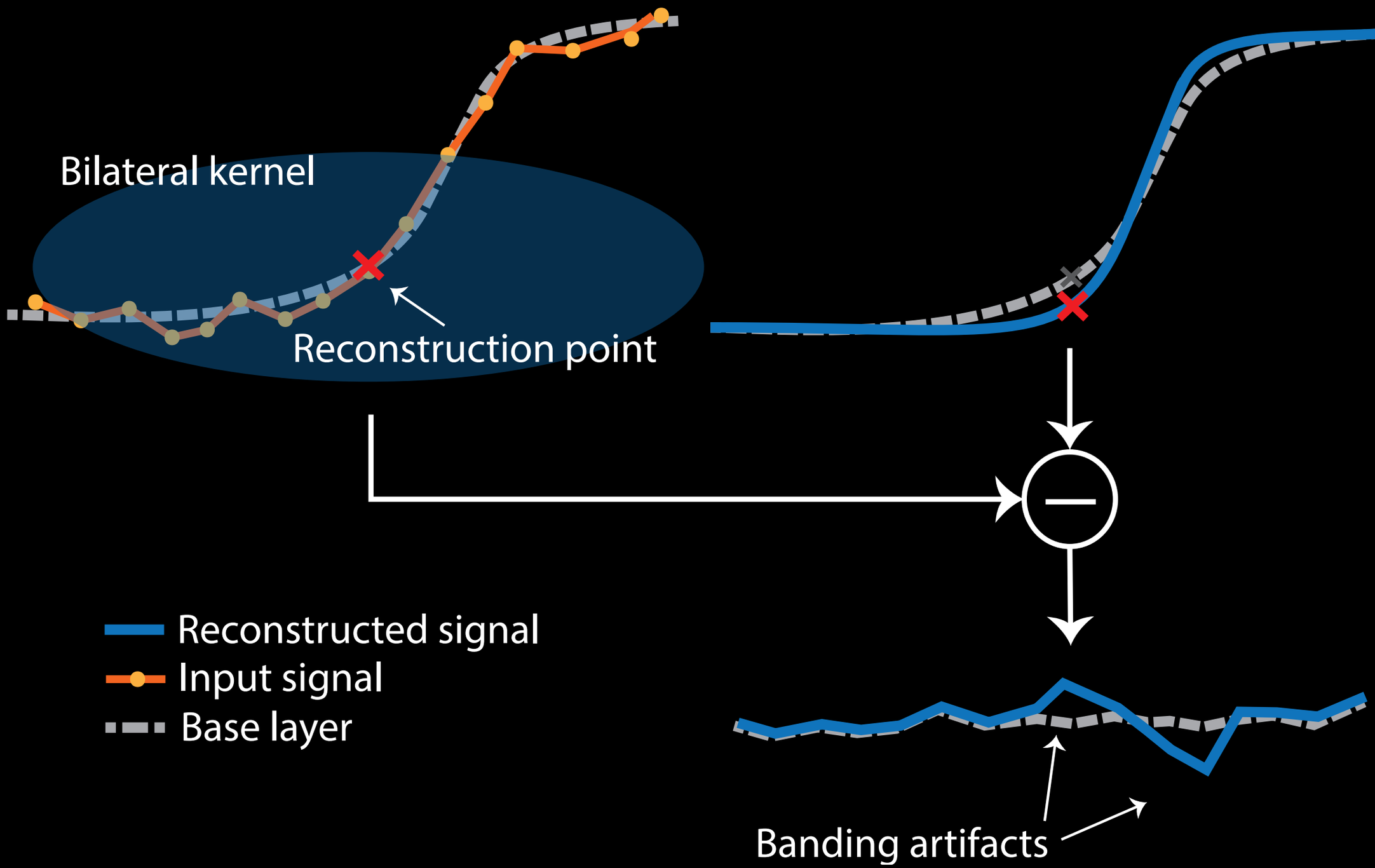
- Ringing/banding artifacts
- Computationally expensive



- *TOMASI, C., AND MANDUCHI, R. 1998. Bilateral filtering for gray and color images. In Proc. International Conference on Computer Vision 6, 839–846*
- *PERONA, P., AND MALIK, J. 1990. Scale-space and edge detection using anisotropic diffusion. IEEE Trans. Pattern Analysis Machine Intelligence 12, 7, 629–639.*

Filtering for tone mapping

Problem statement



Filtering for tone mapping

Fast detail extraction diffusion

$$I(I,\boldsymbol{p}) = \alpha \sum_{\boldsymbol{q}\in\Omega_{\boldsymbol{p}}} \omega_s(||\boldsymbol{q}-\boldsymbol{p}||)\,\omega_r(I(\boldsymbol{q})-I(\boldsymbol{p}))\; I(\boldsymbol{q})$$

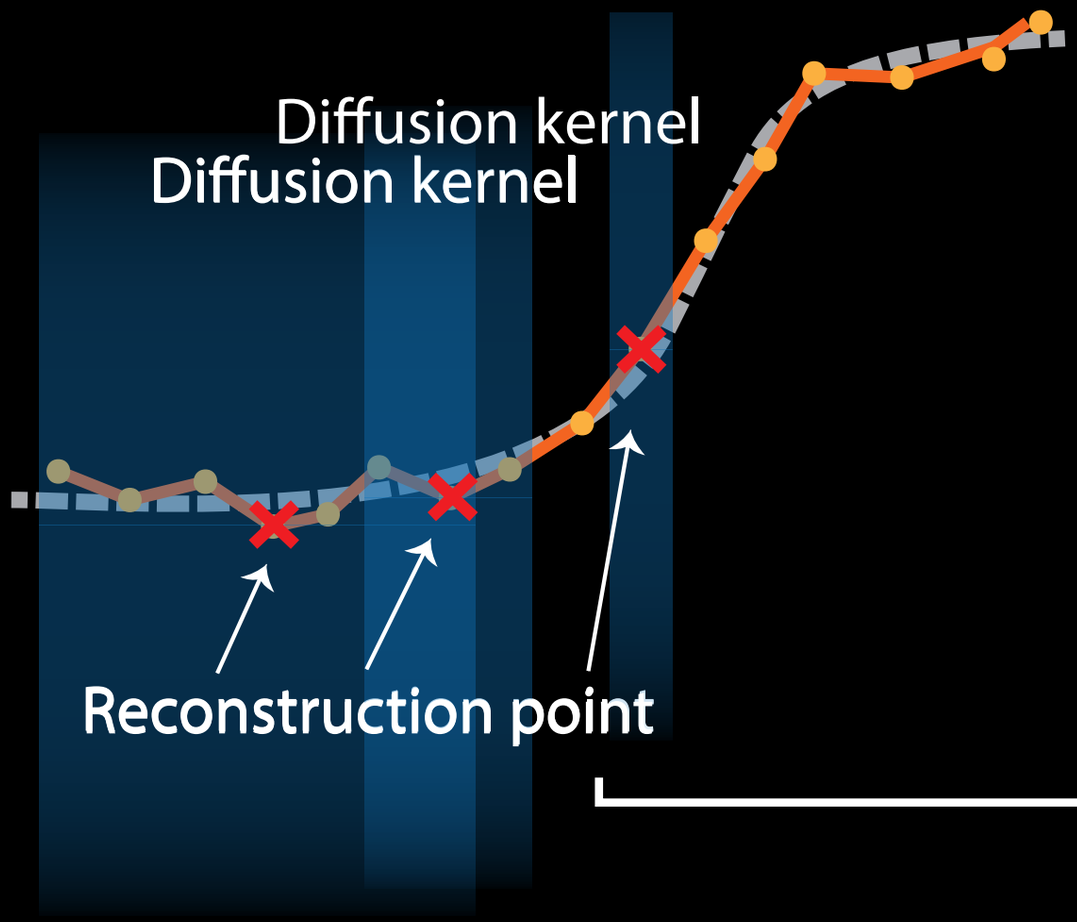
$$\begin{cases} V(I,\boldsymbol{p}) = \displaystyle\sum_{\boldsymbol{q}\in\Omega_{\boldsymbol{p}}} \omega_s(||\boldsymbol{q}-\boldsymbol{p}||)\,\omega_r(I(\boldsymbol{q})-I(\boldsymbol{p}))\; I(\boldsymbol{q}) \\ I^{k+1} = (1-\omega_r)I^k(\boldsymbol{p}) + V(I^k,\boldsymbol{p}) \end{cases}$$

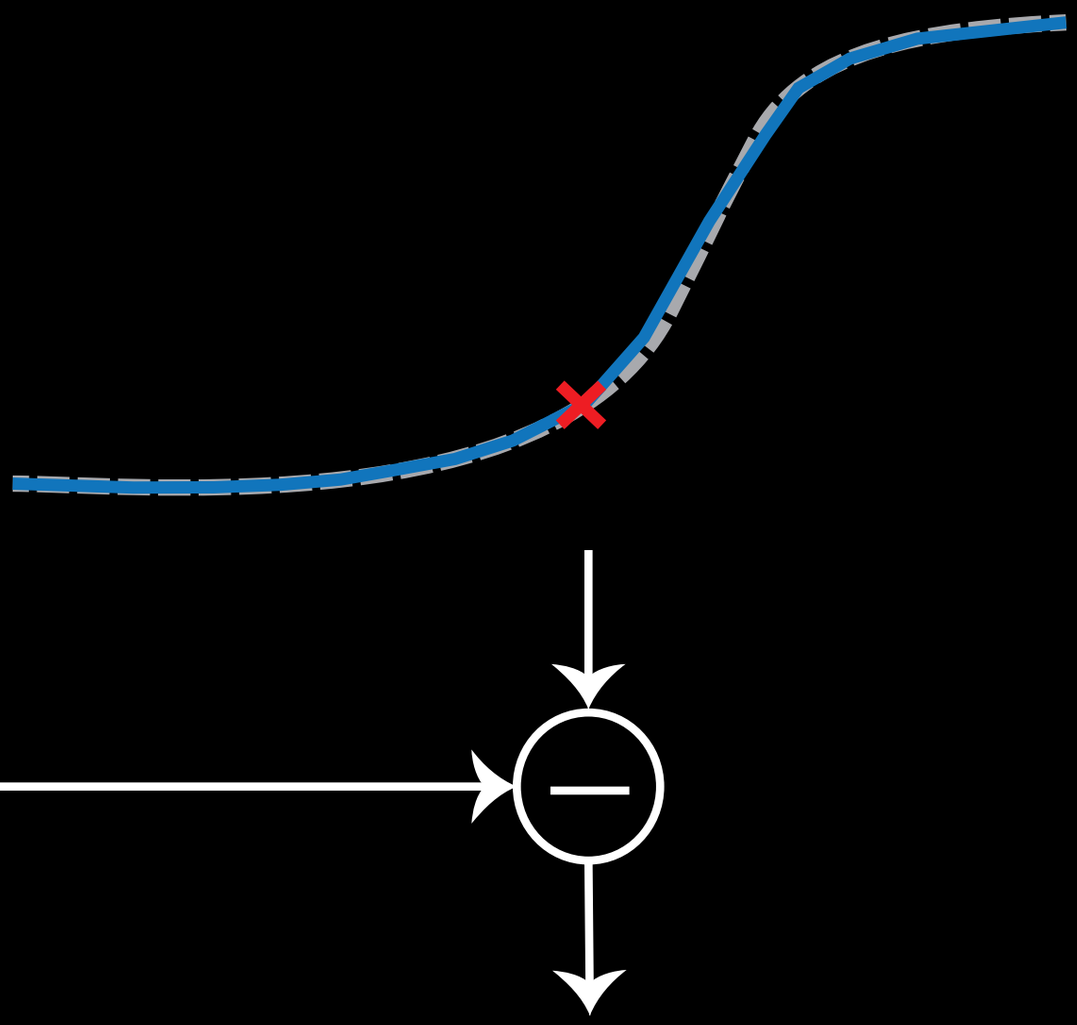
$\omega_r(||\nabla I(\boldsymbol{p})||)$

ω_s	-	Spatial filter
ω_r	-	Edge-stop function
$\boldsymbol{p}$	-	Reconstruction point
$\Omega_{\boldsymbol{p}}$	-	Local neighborhood

Filtering for tone mapping

Fast detail extraction diffusion

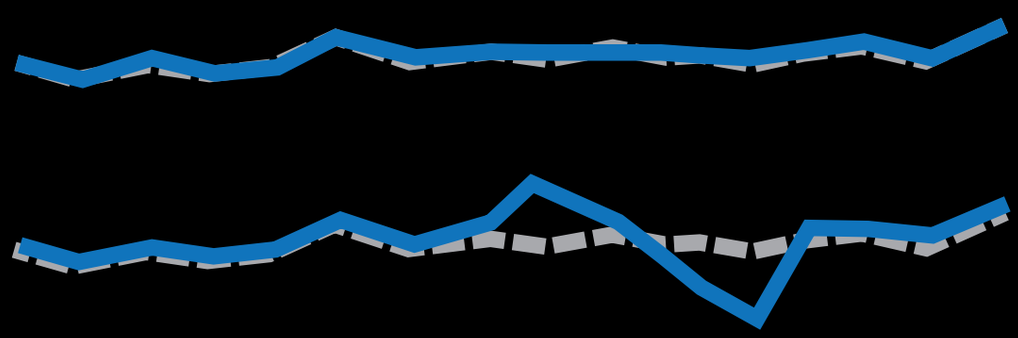




Reconstructed signal

Input signal

Base layer



Bilateral filter

Bilateral filter | Anisotropic diffusion | Fast local laplacian

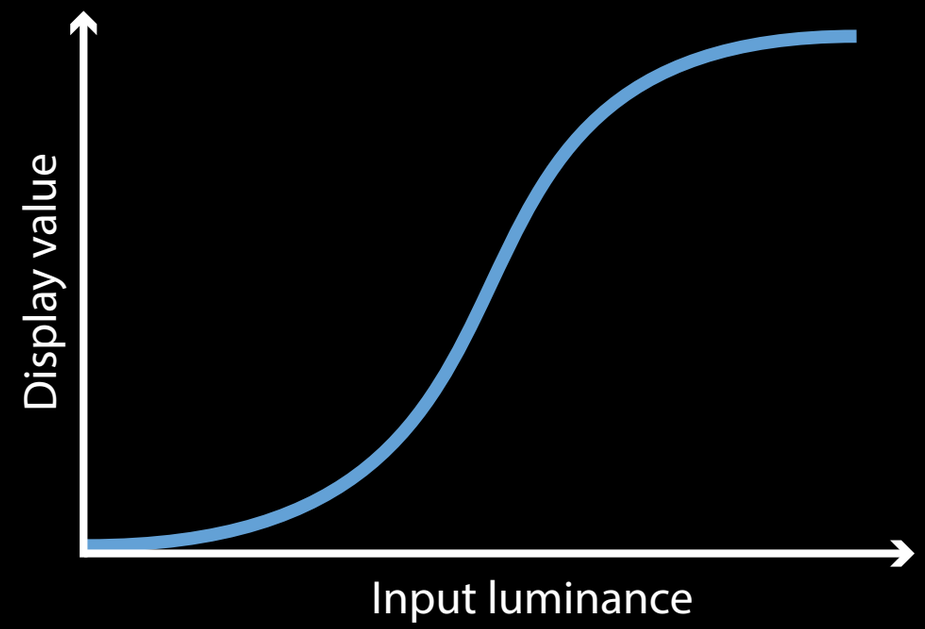
Permeability filter | Our approach

- *AUBRY, M., PARIS, S., HASINOFF, S. W., KAUTZ, J., AND DU- RAND, F. 2014. Fast local laplacian filters: Theory and applications. ACM Trans. Graphics 33, 5, 167:1–167:14.*
- *AYDIN, T. O., STEFANOSKI, N., CROCI, S., GROSS, M., AND SMOLIC, A. 2014. Temporally coherent local tone mapping of HDR video. ACM Trans. Graphics 33, 6, 1–13.*

Minimum contrast distortion Definition

Contrast distortion

- A tone-curve controls how much contrast is compressed at each luminance level
- Contrasts are distorted in the process



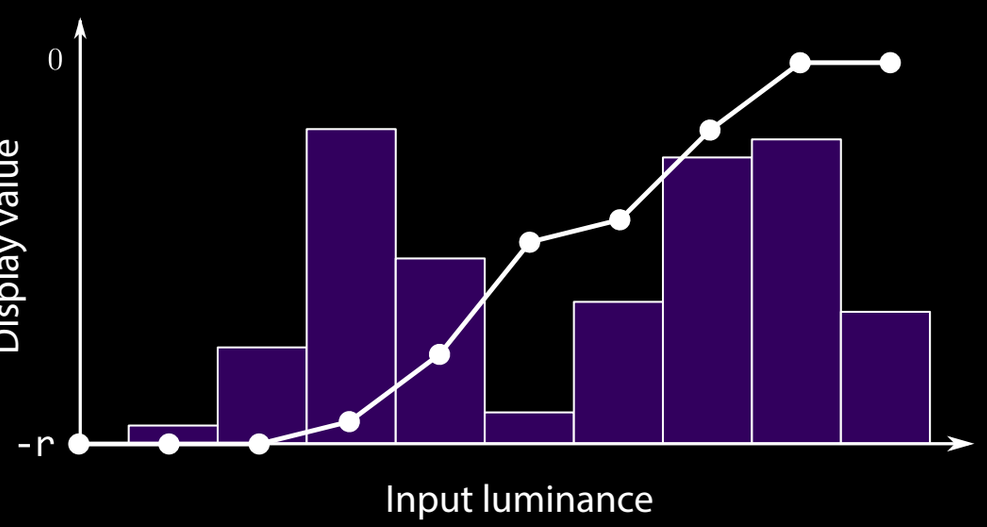
- *HUNT, R. 2004. The Reproduction of Colour in Photography, Printing and Television: 6th Edition. John Wiley & Sons.*

Minimum contrast distortion

Tone-curve derivation

Minimizing contrast distortions

- General optimization problem
- Analytical solution
- Very fast solver



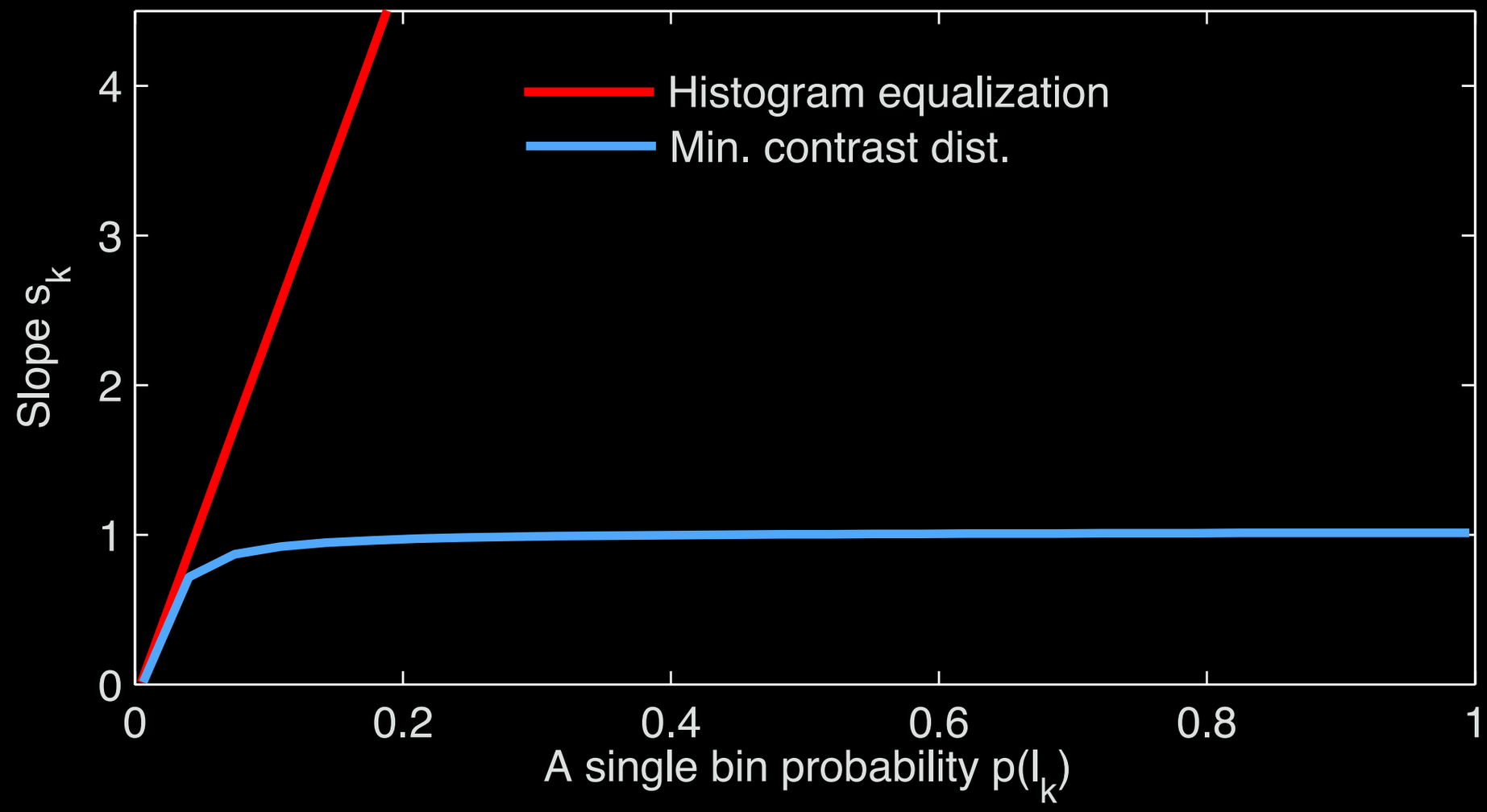
$$\arg\min_{T} ||G(I) - G(T(I))||$$

Subject to: $T(I)$ within the dynamic range of the display

I	-	HDR image
$G(I)$	-	Image contrast
T	-	Tone-curve

Minimum contrast distortion

Tone-curve comparison



- *MAI, Z., MANSOUR, H., MANTIUK, R., NASIOPOULOS, P., WARD, R., AND HEIDRICH, W. 2011. Optimizing a tone curve for backward-compatible high dynamic range image and video compression. IEEE Trans. Image Processing 20, 6, 1558 – 1571.*

Minimum contrast distortion

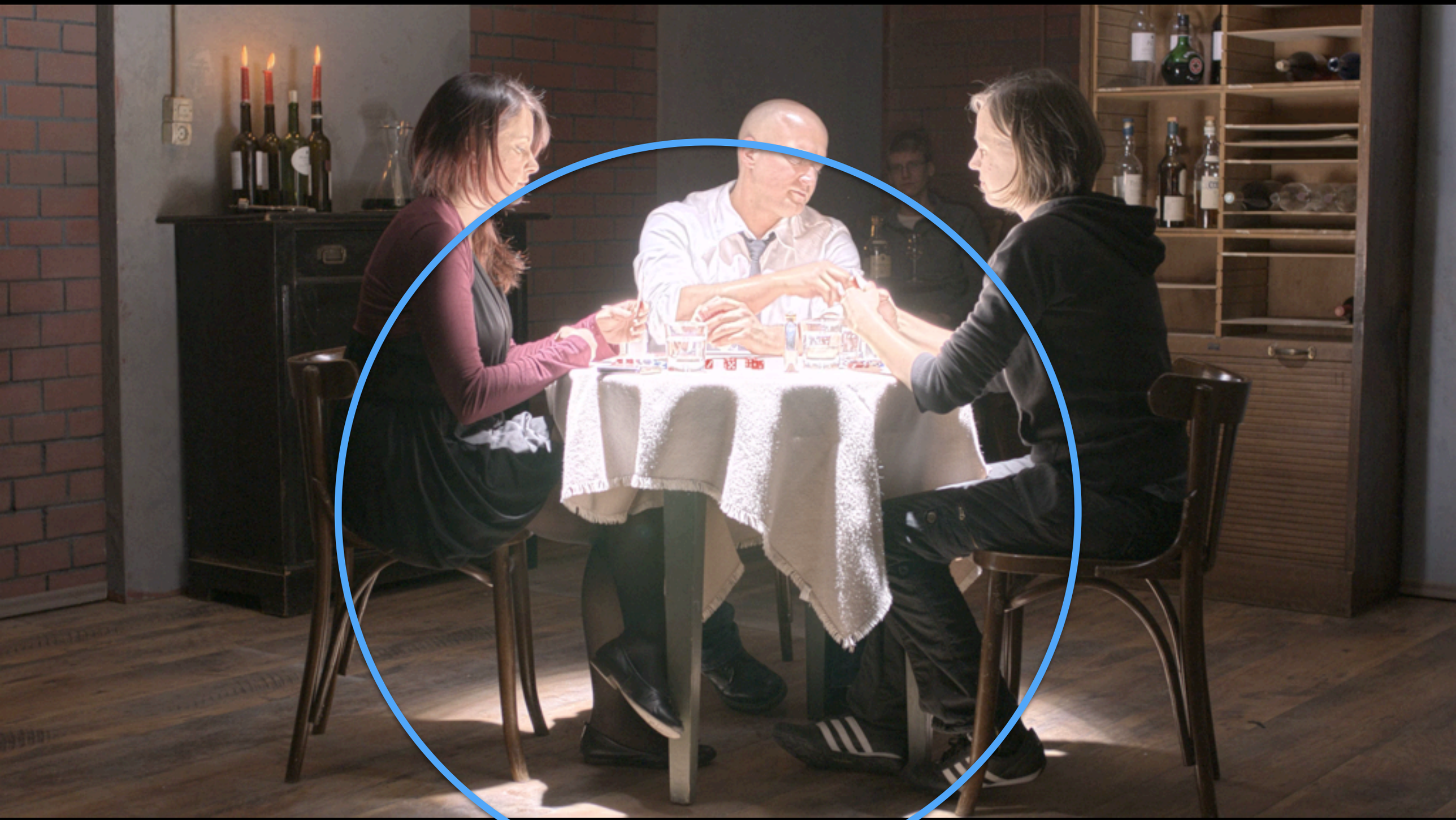
Spatial & temporal considerations

Local tone-curves

- Local areas of 5 visual degrees
- Blended with global tone-curve
- Applied by interpolation

Temporal filtering

- Prevents flickering
- IIR filter
- Edge-stop filter



Noise-aware processing

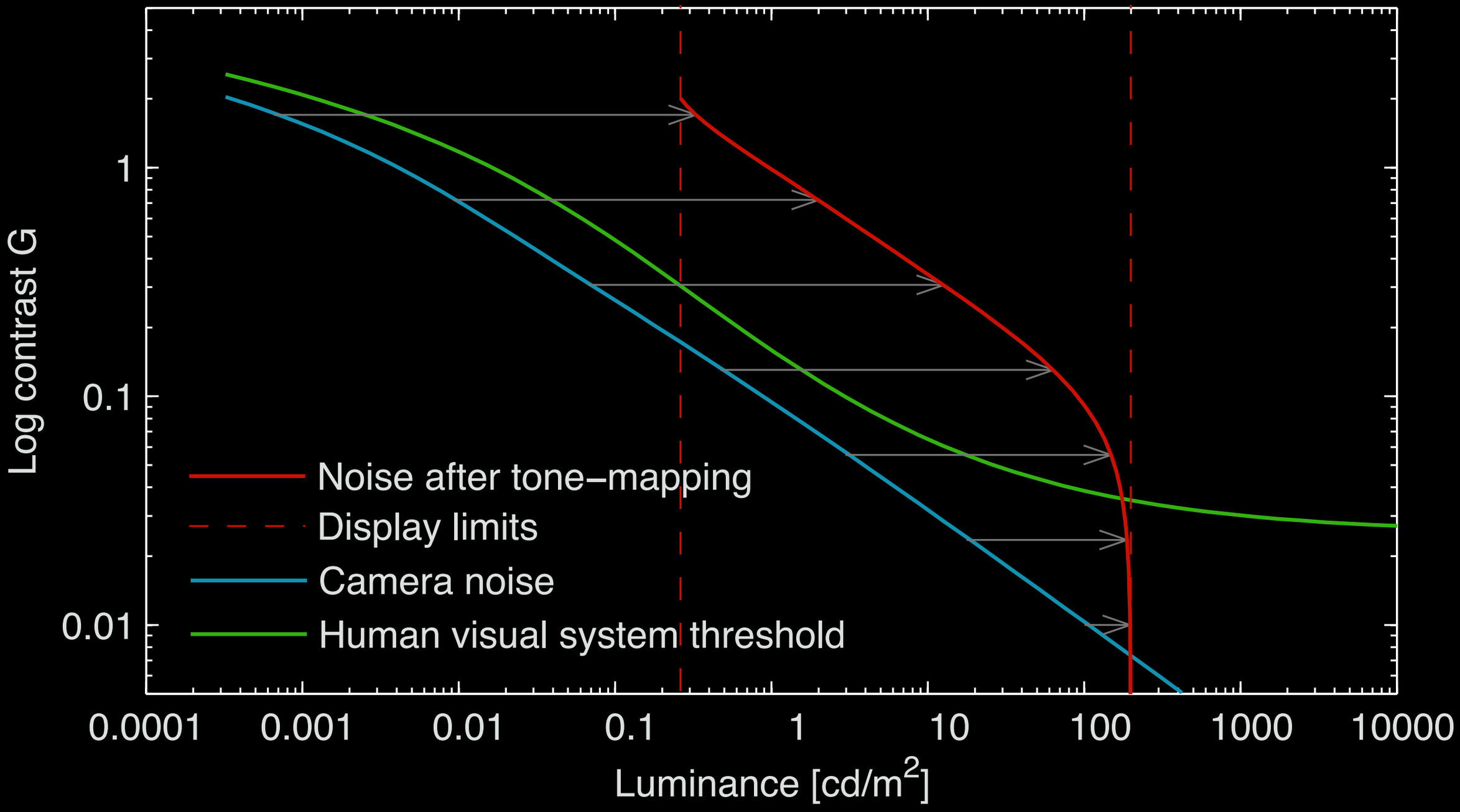
Problem statement

HDR input

Tone mapped output

Noise-aware processing

Problem statement



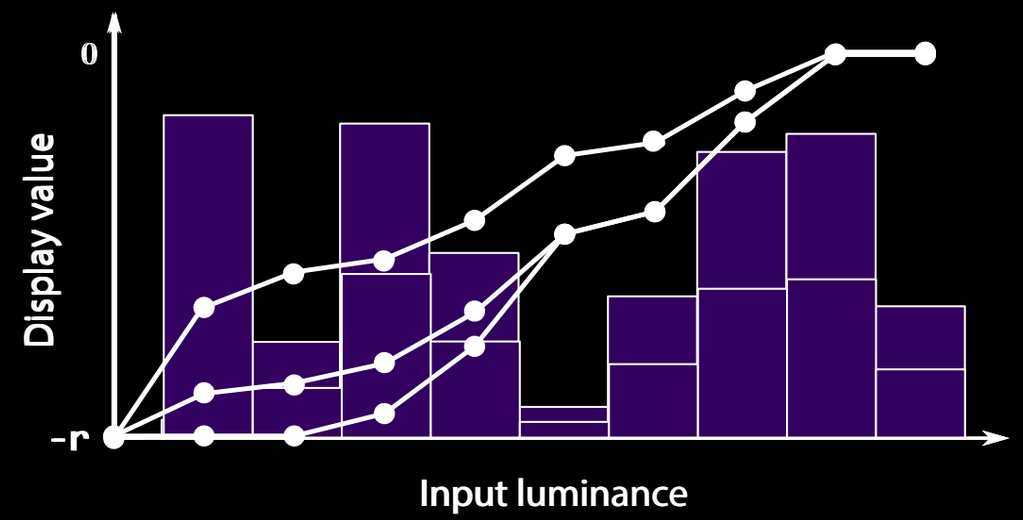
Noise-aware processing Definition

Noise increased by tone mapping

Noise-aware tone-curves

Noise-aware detail manipulation

Complementary to denoising



HDR input

Edge-pres. filter
(fast detail extraction diffusion)

Base layer

Detail layer

Tone mapping

Local tone-curves
(noise-aware contrast distortion)

Noise-awareness
(scaling of detail layer)

Noise model

HDR input

Edge-pres. filter
(fast detail extraction diffusion)

Base layer

Detail layer

Tone mapping

Display adaptation
(inverse display model)

Local tone-curves
(noise-aware minimum contrast distortion)

Noise-awareness
(scaling of detail layer)

Noise model

Demonstration

Real-time screen capture

Conclusion

- Minimum contrast distortion
- Noise-awareness
- Fast detail extraction diffusion
- Display adaptation
- Real-time

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Thanks to Fröhlich et al. for providing HDR video sequences

HDR videos available at: hdr-2014.hdm-stuttgart.de

- *FROEHLICH, J., GRANDINETTI, S., EBERHARDT, B., WALTER, S., SCHILLING, A., AND BRENDEL, H. 2014. Creating Cinematic Wide Gamut HDR-Video for the Evaluation of Tone Mapping Operators and HDR-Displays. In Proc. SPIE 9023, Digital Photography X, 90230X–90230X–10.*

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Visual Computing Laboratory: vcl.itn.liu.se

Luma HDR video encoding: lumahdrv.org

http://vcl.itn.liu.se

http://www.itn.liu.se/mit/research/computer-graphics-image-processing/real-time-noise-aware-tone-mapping

HDR video sequences from:
https://hdr-2014.hdm-stuttgart.de

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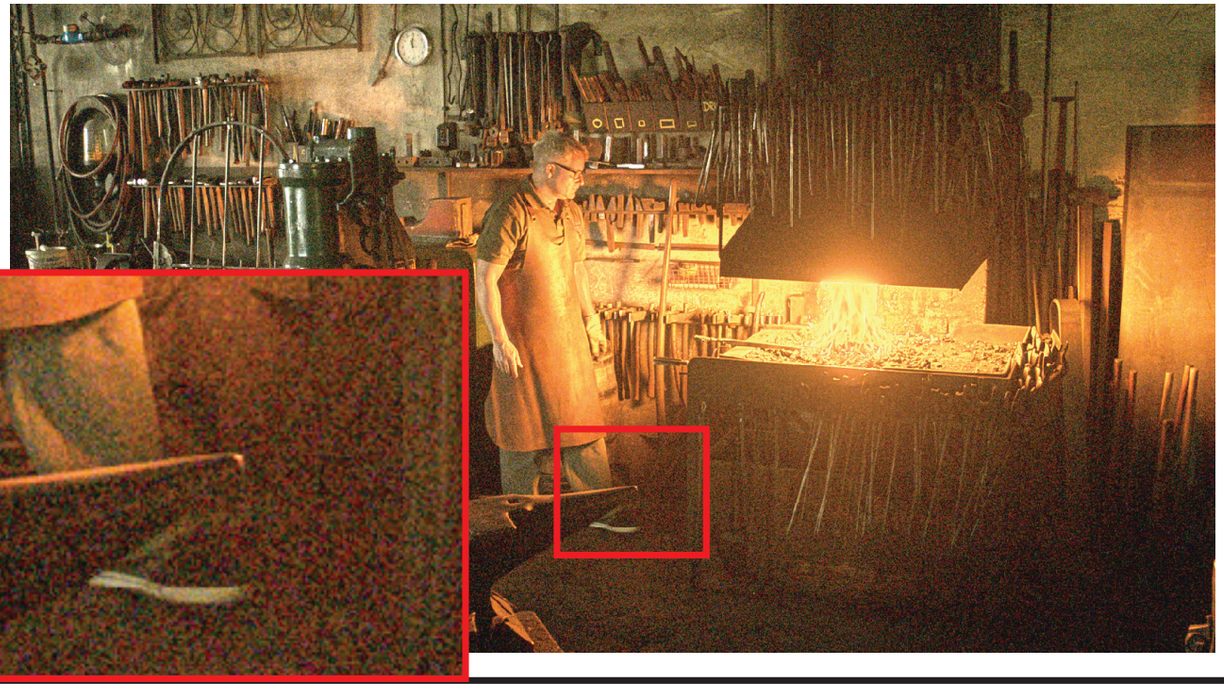
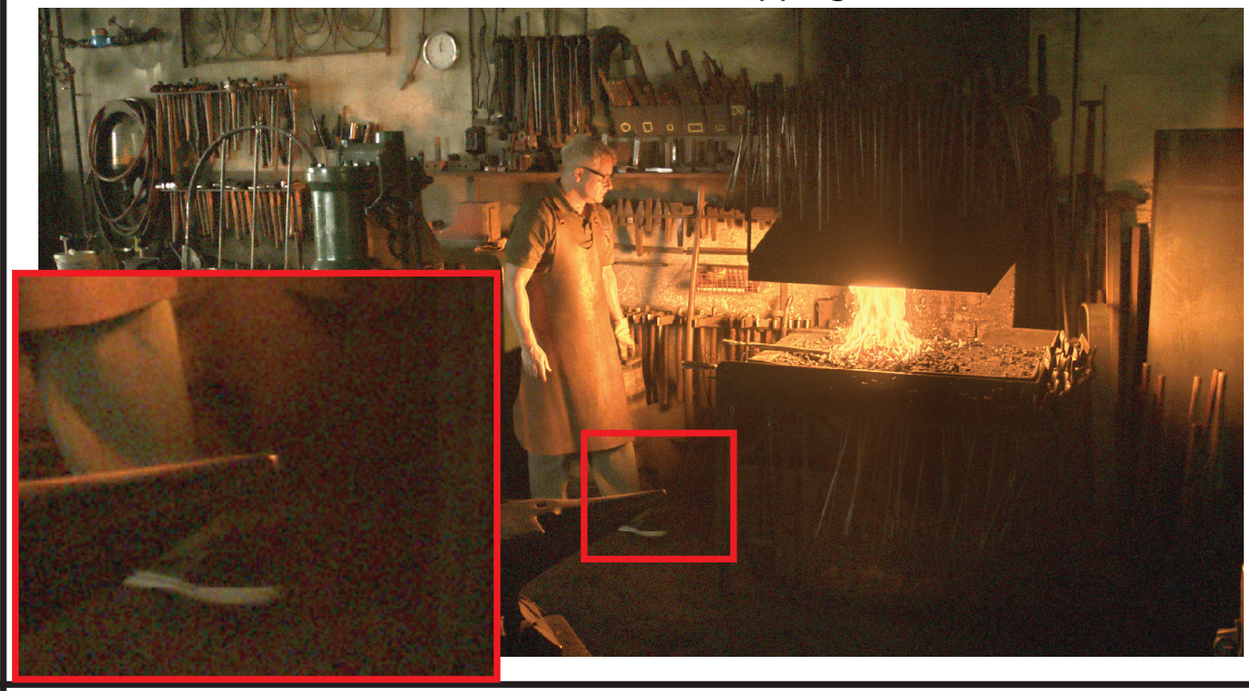
Naïve tone mapping

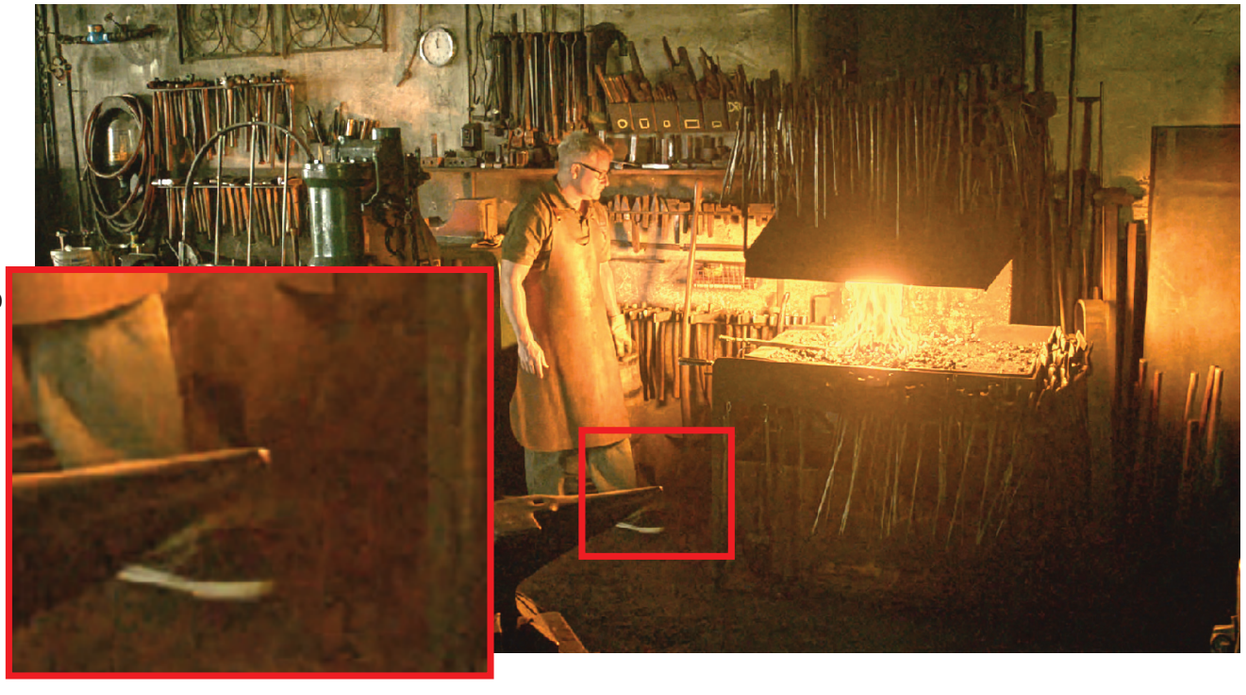
Noise-aware tone mapping

Without denoising





With denoising (V-BM4D)



- *MAGGIONI, M., BORACCHI, G., FOI, A., AND EGIAZARIAN, K. 2012. Video denoising, deblocking, and enhancement through separable 4-d nonlocal spatiotemporal transforms. IEEE Trans. Image Processing 21, 9, 3952–3966.*

Noise-aware tone mapping

Naive tone mapping

Local tone-curves

Global tone-curve

Ambient light: 1000 lux

Ambient light: 3000 lux

No compensation

Display-adaptive TMO

Our adaptive TMO

Our

Guided filter, 5x5

Guided filter, 10x10

Bilateral filter

Anisotropic diffusion

Fast local laplacian

Permeability filter

Our approach