Image / Video Quality Assessment

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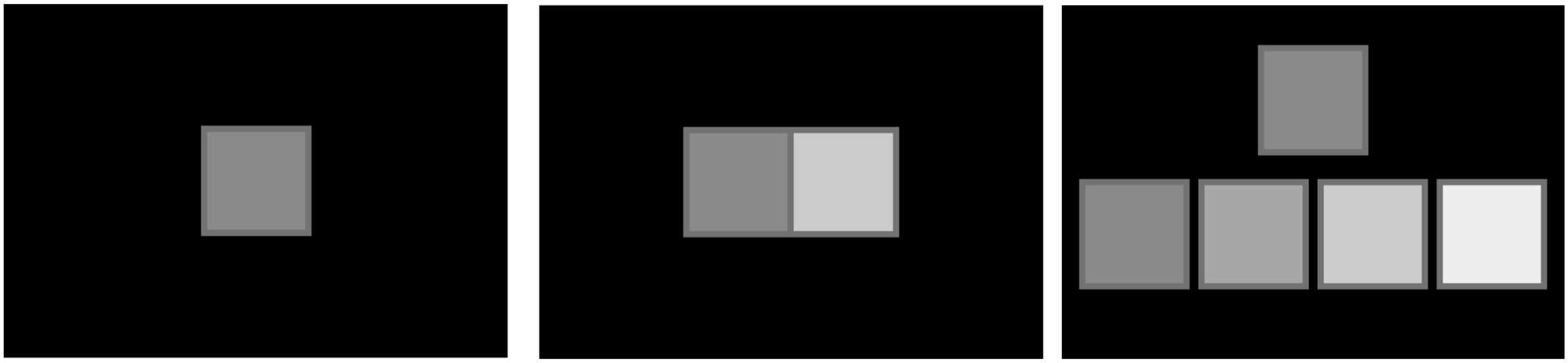
Problem Definition

Rate the Quality

Subjective Quality Assessment

Figures taken from [Ferwerda 2008]



Detection Discrimination Scaling

Refer to: [James Ferwerda, Psychophysics 101: How to Run Perception Experiments in Computer Graphics, SIGGRAPH 2008].

+ Reliable **- High cost**

Objective Quality Assessment

No Reference

Reduced Reference

Full Reference

Refer to: [Wang & Bovik, Modern Image Quality Assessment, 2008].

Generic Quality Assessment Workflow

Reference

Test

Distortion Map

Simple Distortion Metrics

- **Mean Squared Error (MSE)**

$$MSE(x,y) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2$$

- **Peak Signal to Noise Ratio (PSNR)**

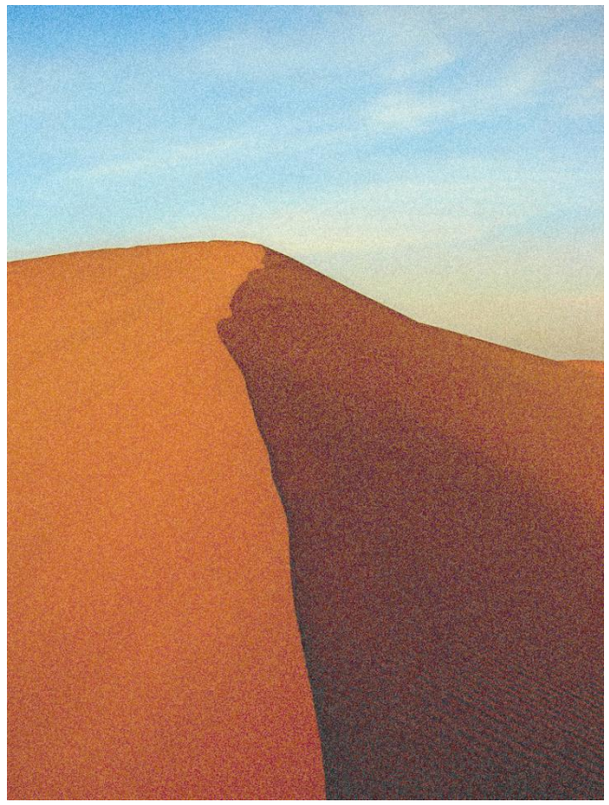
$$PSNR(x,y) = 10\log_{10}\frac{L^2}{MSE}$$

- **Structural Similarity Index Metric (SSIM):** More sophisticated, accounts for luminance contrast and structural distortions

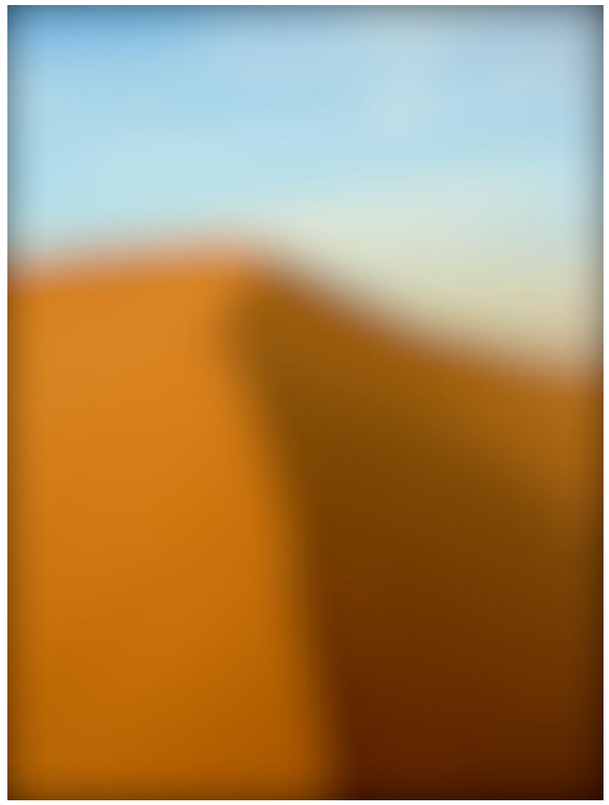
$$SSIM(x,y) = l(\mu_x,\mu_y)^{\alpha}\, c(\sigma_x,\sigma_y)^{\beta}\, s(\sigma_x,\sigma_y)^{\gamma}$$

Limitations of Simple Distortion Metrics

Reference



Random Noise



Blur

~15% Decreased Luminance

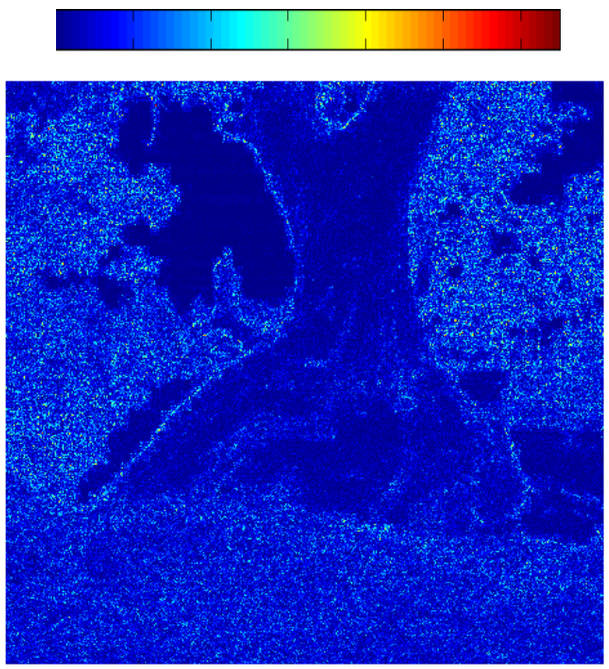
Same MSE for all three images!

Perception of Distortions

Reference
(bmp, 616K)

Compressed
(jpg, 48K)

Low High

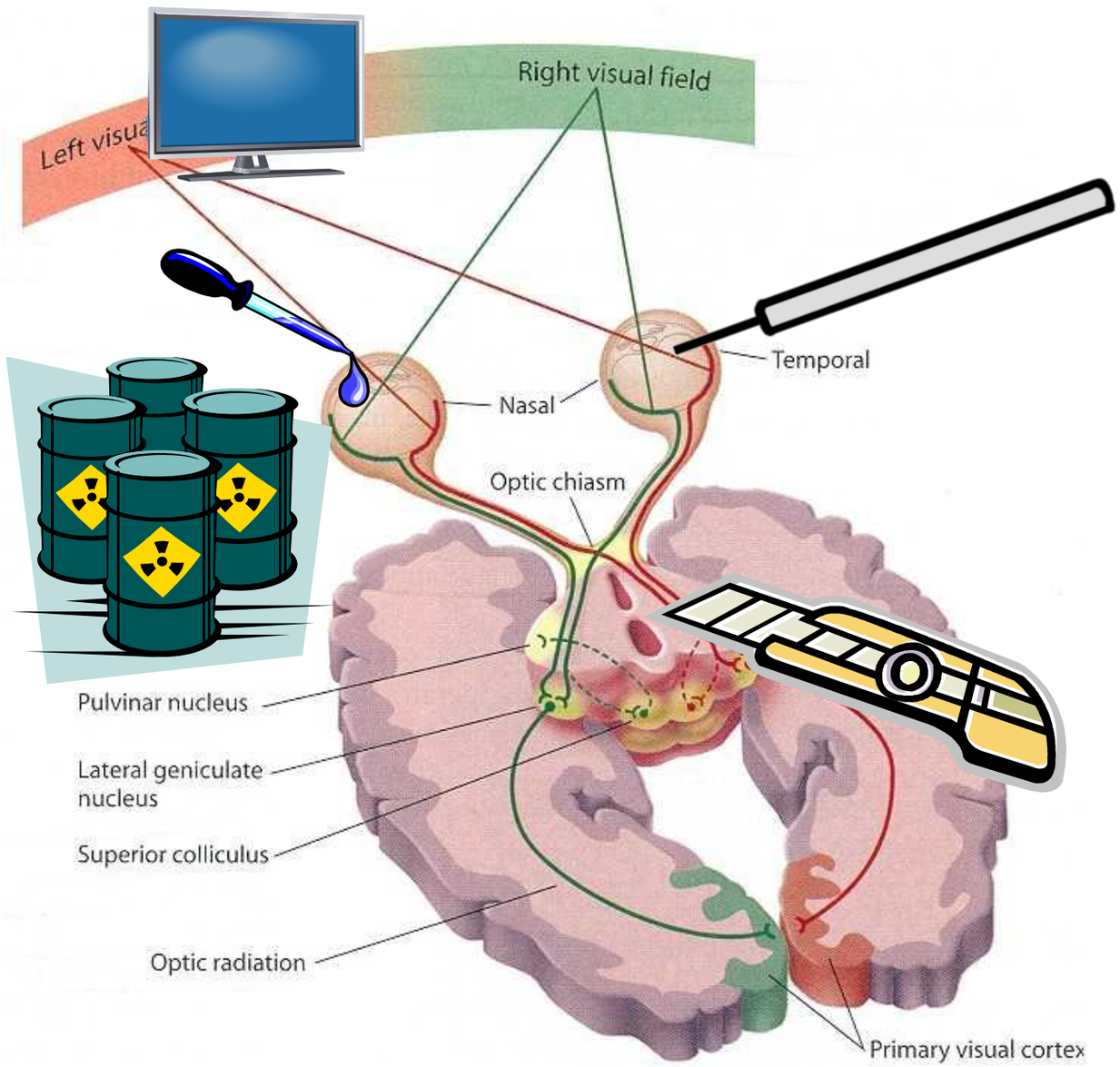


Difference Image
(Color coded)

Limitations of Simple Distortion Metrics, cont.

Visible difference doesn’t always mean lower quality!

The Human Visual System (HVS)



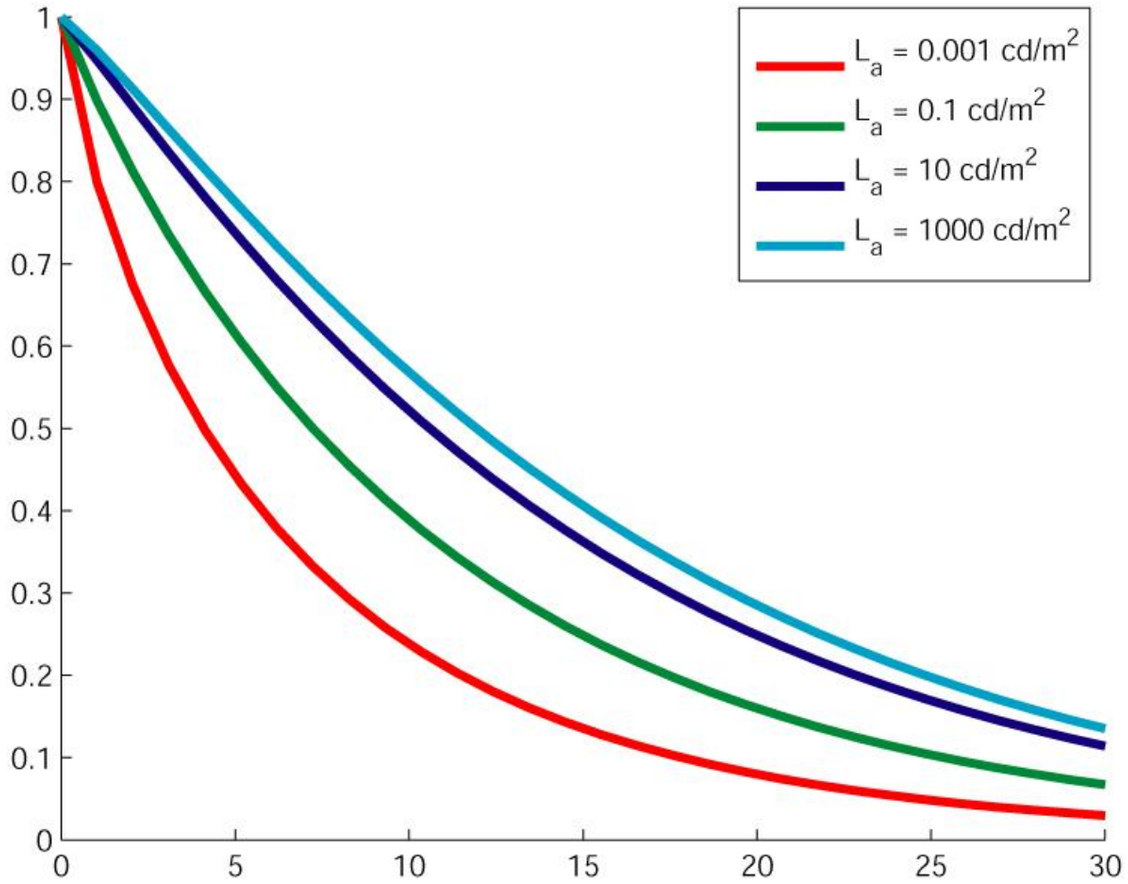
- Experimental Methods of Vision Science
  - Micro-electrode
  - Radioactive Marker
  - Vivisection
  - Psychophysical Experimentation

HVS effects: (1) **Glare**

Video Courtesy of Tobias Ritschel

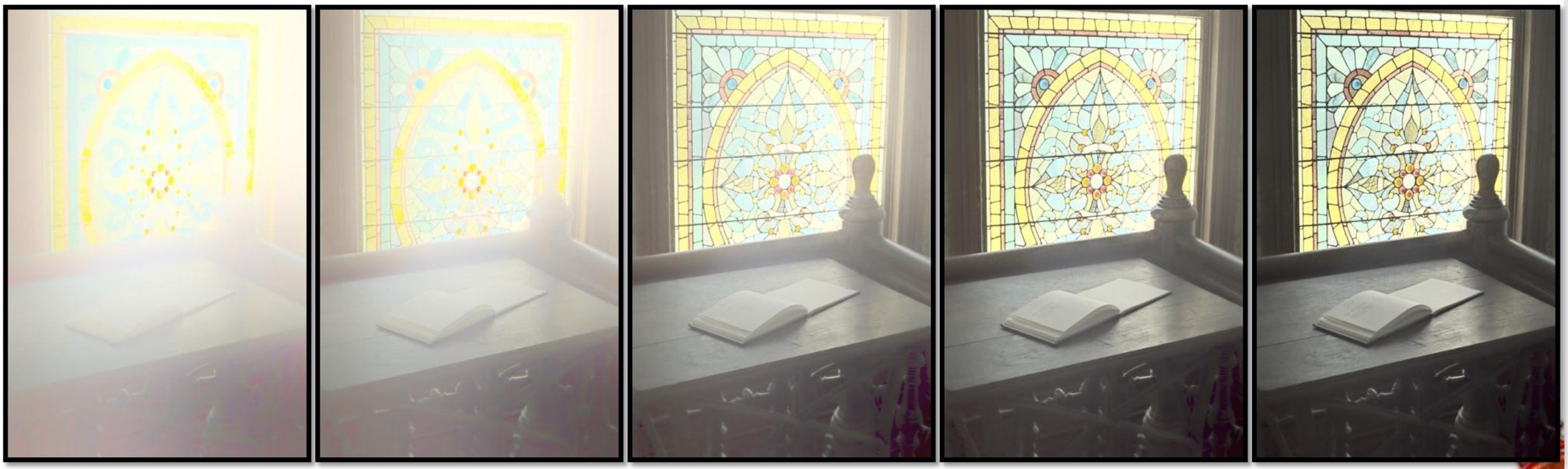
- **Disability Glare** (blooming)

Disability Glare



- Model of Light Scattering
  - Point Spread Function in spatial domain
  - Optical Transfer Function in Fourier Domain [Deeley et al. 1991]

(2) Light Adaptation

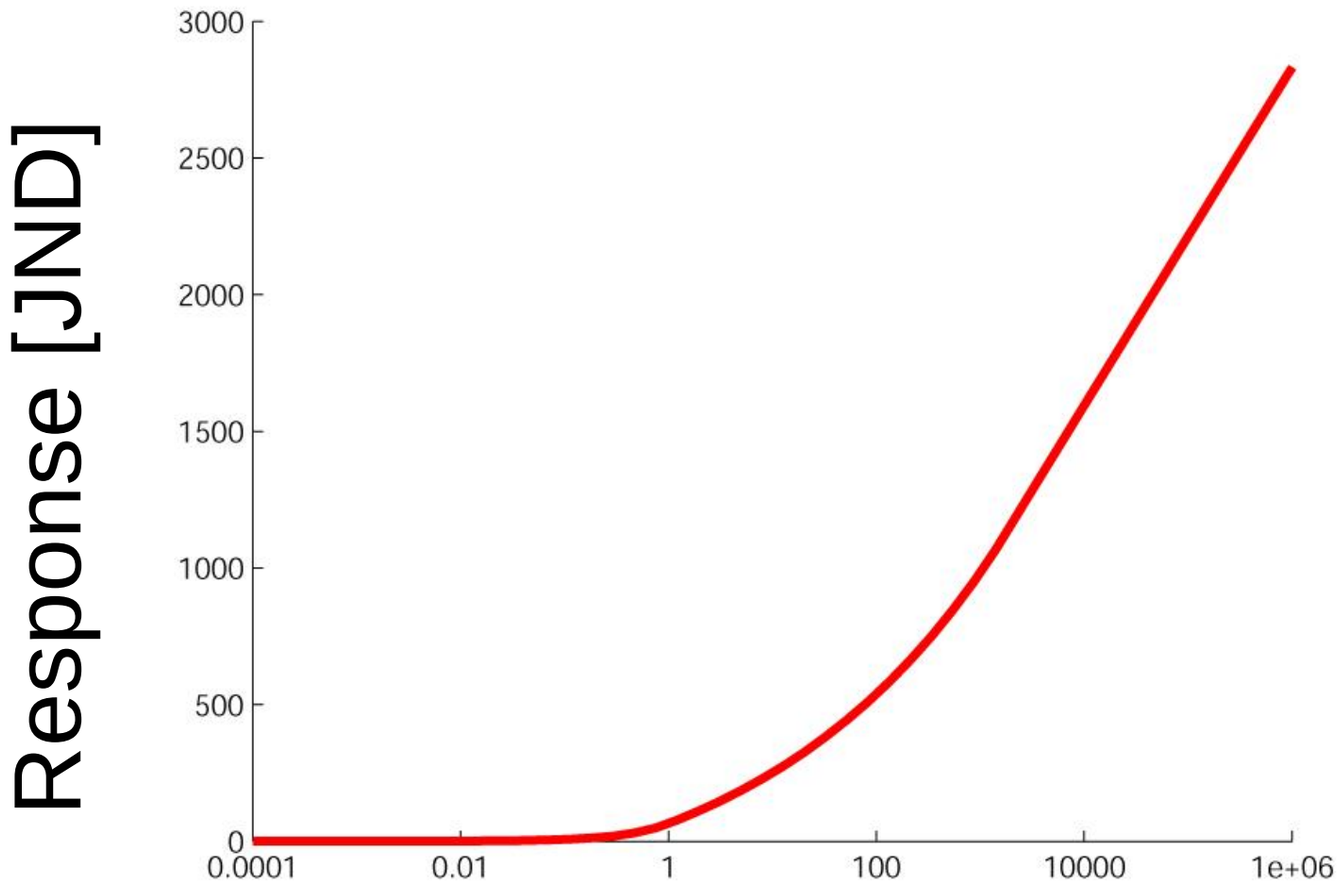


Adaptation Level:
10^{-4} cd/m^2

Time ⟶

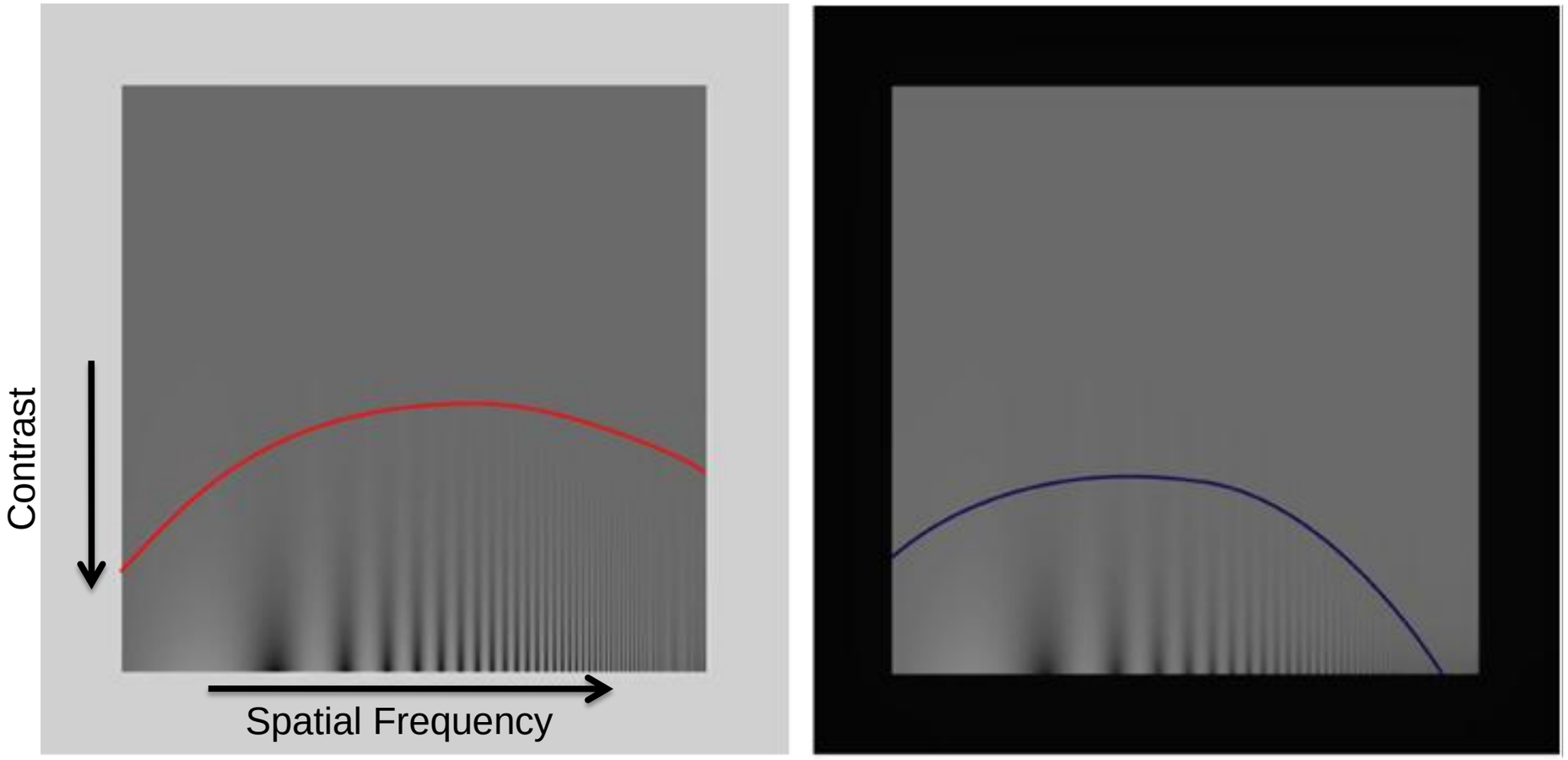
Adaptation Level:
17 cd/m^2

Perceptually Uniform Space



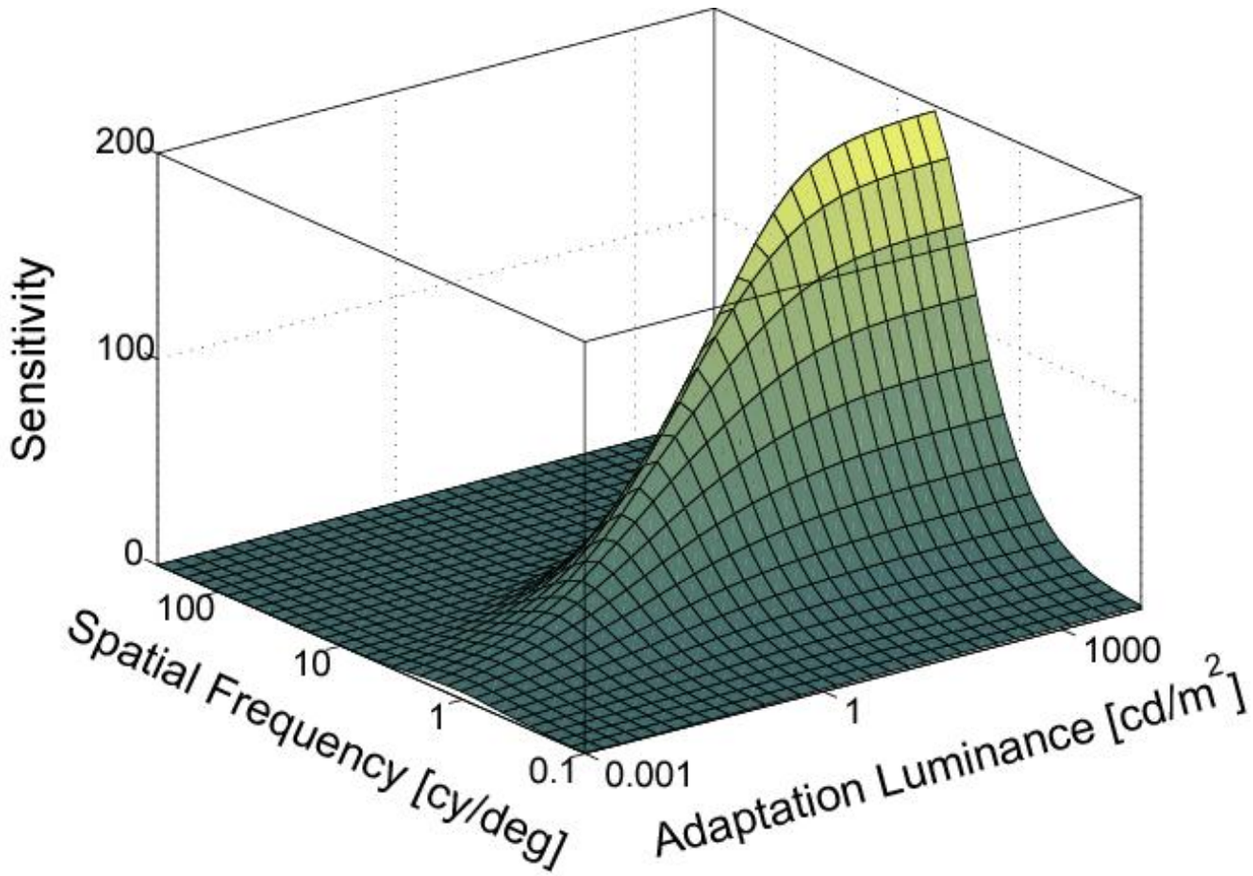
- Transfer function: Maps **Luminance** to **Just Noticeable Differences (JNDs)** in Luminance. [Mantiuk et al. 2004, Aydın et al. 2008]

(3) Contrast Sensitivity



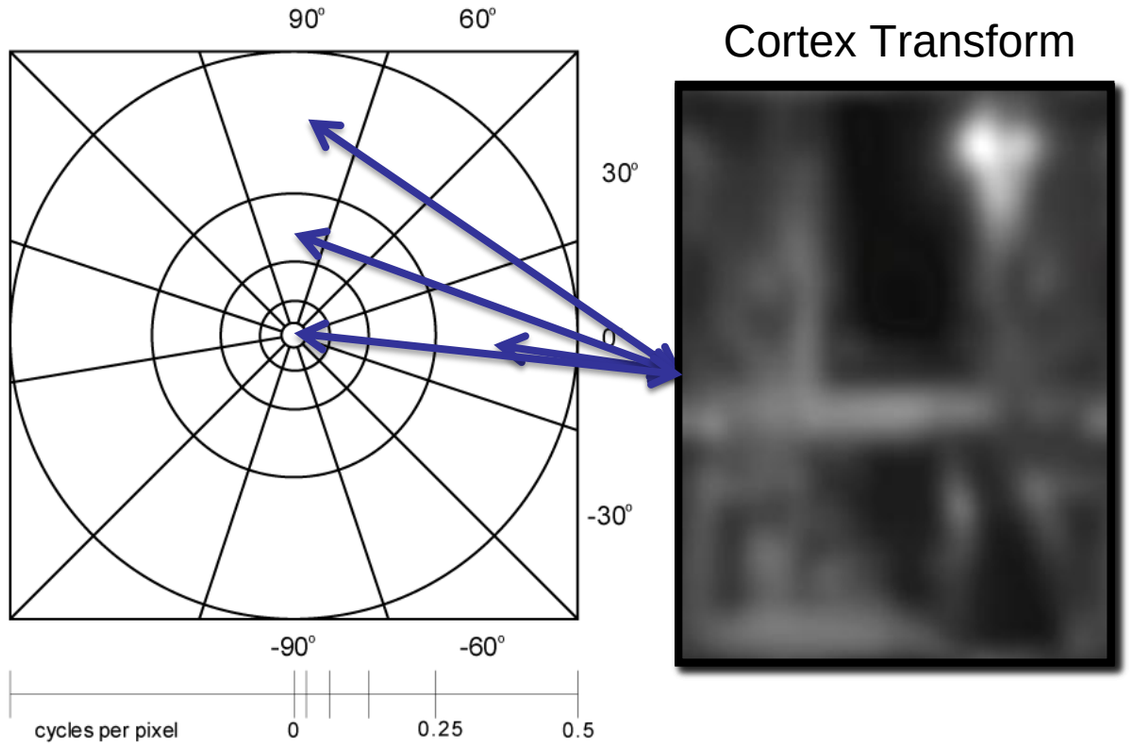
CSF(spatial frequency, adaptation level, temporal freq., viewing dist, …)

Contrast Sensitivity Function (CSF)

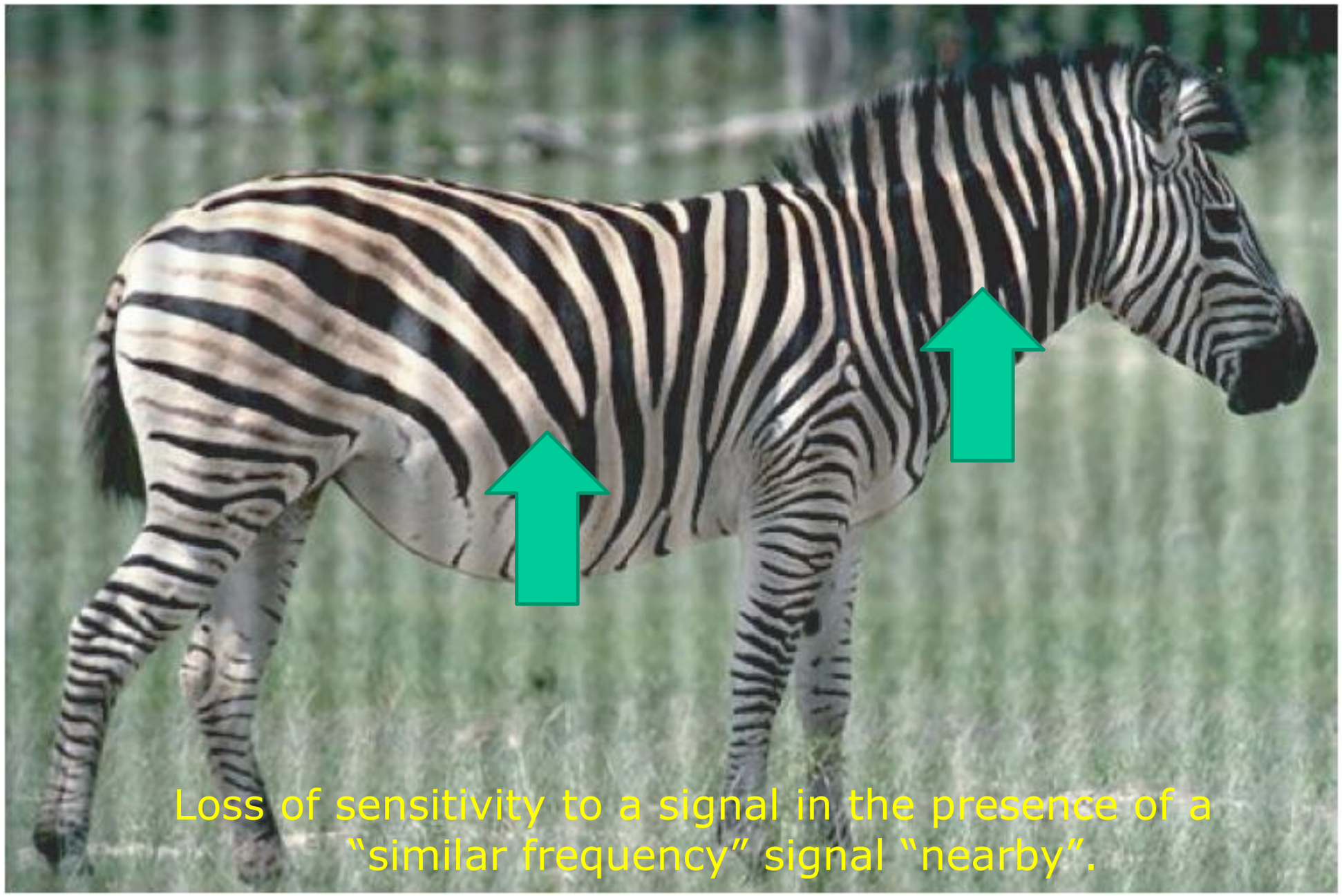


- Steady-state CSF[S]: Returns the Sensitivity (1/Threshold contrast), given the adaptation luminance and spatial frequency [Daly 1993, Mantiuk et al. 2011].

(4) Visual Channels

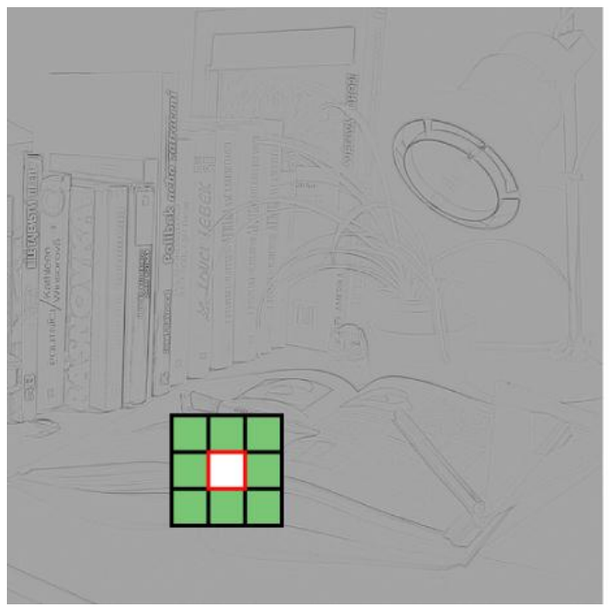


(5) Visual Masking

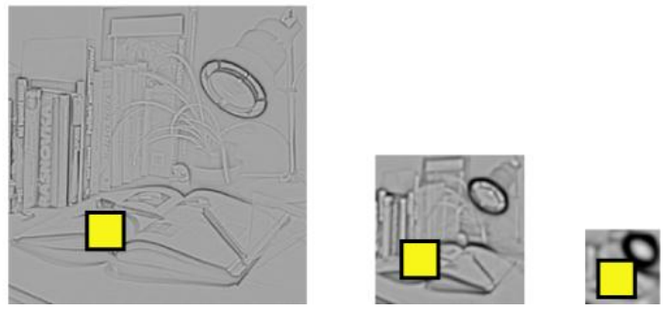


Loss of sensitivity to a signal in the presence of a "similar frequency" signal "nearby".

Visual Masking Models



- Masked coefficient
- Intra-channel neighborhood
- Inter-channel neighborhood

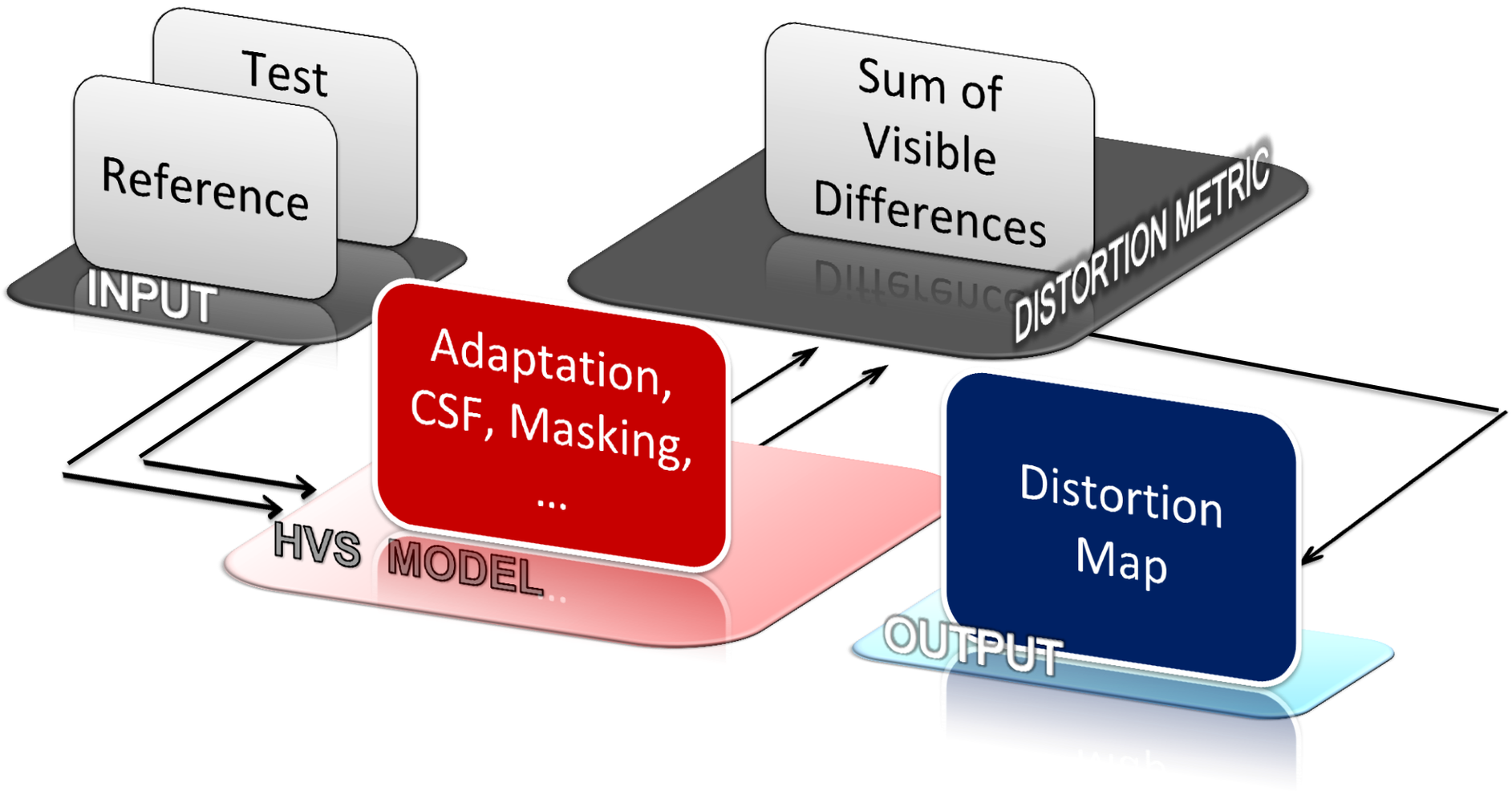


- **Example:** JPEG's pointwise extended masking:

$$R = \frac{sign(C')|C'|^{0.5}}{(1 + \sum_K |C'_k|^{0.2})}$$

C': Normalized Contrast

Generic HVS-based Quality Assessment Workflow

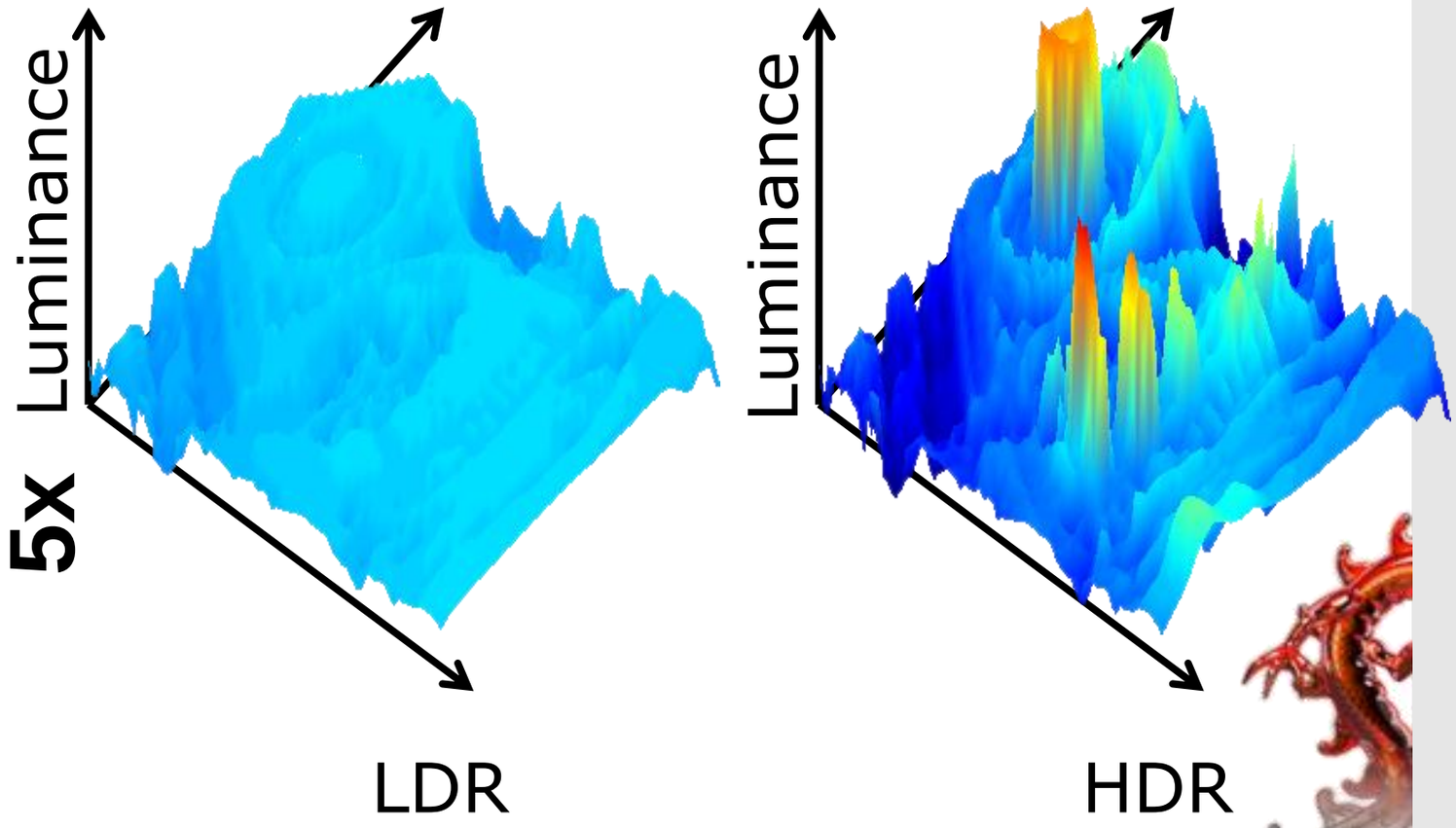


Visible Differences Predictor (VDP) [Daly 93, Mantiuk et al. 05, Mantiuk et al. 11],

Visual Discrimation Model (VDM) [Lubin 95]

QA of Retargeted Images?
HDR Tone mapping case

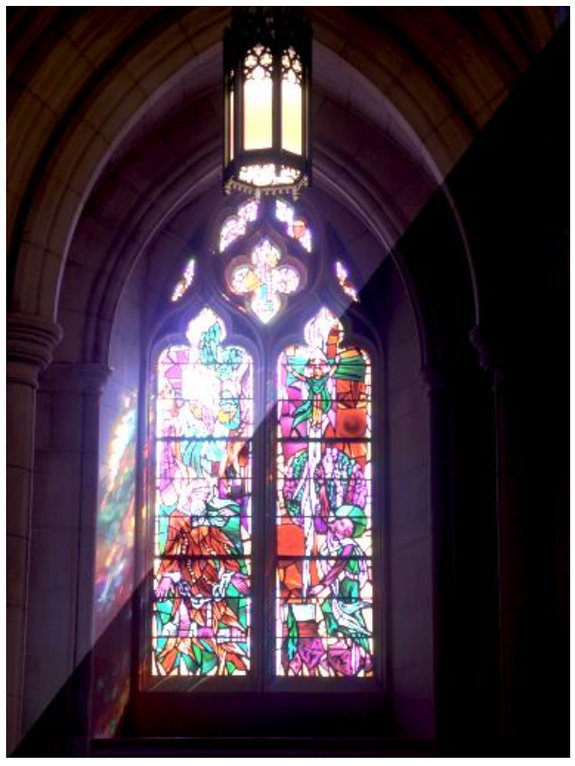
LDR HDR



Case Study

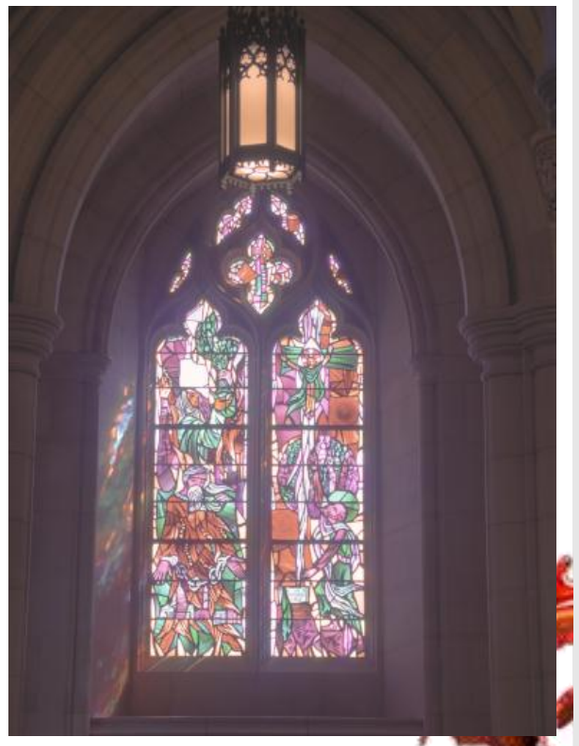
Local Gaussian Blur

HDR Test



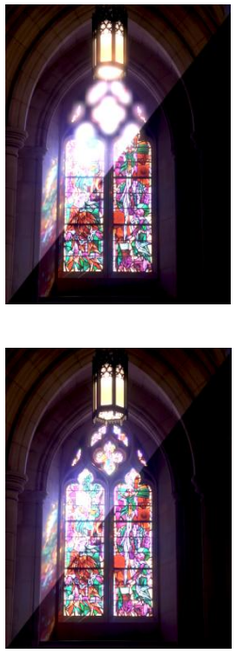
HDR Reference

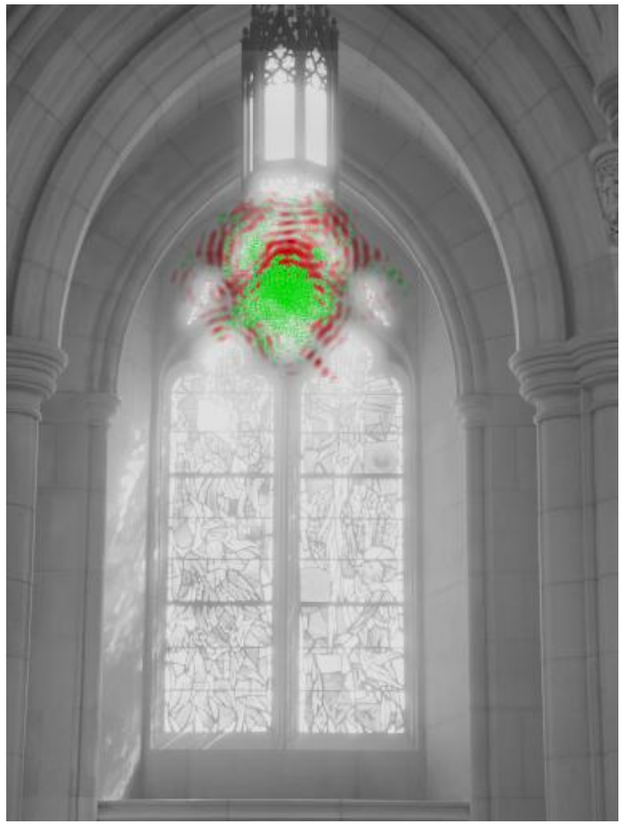
LDR Test



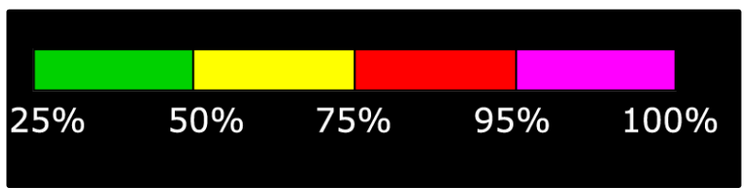
LDR Reference

(1) HDR pair





HDR-VDP SSIM DRI-IQM



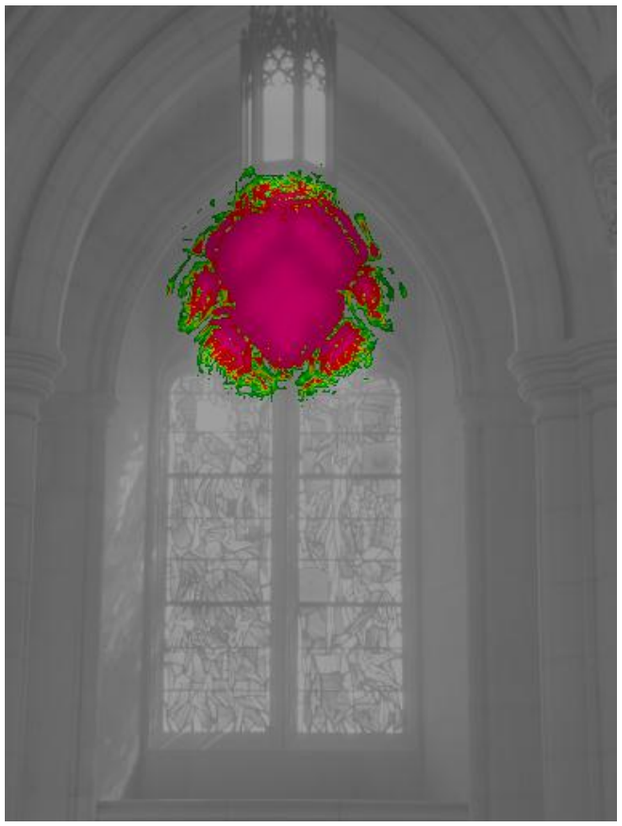
Detection Probability

Loss

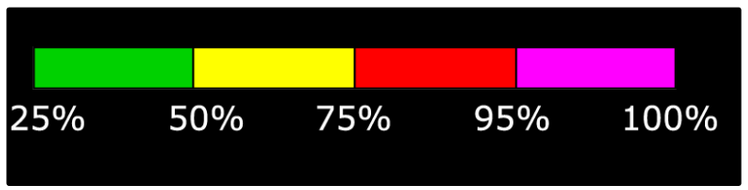
Amplification

Reversal

(2) LDR pair



HDR-VDP SSIM DRI-IQM



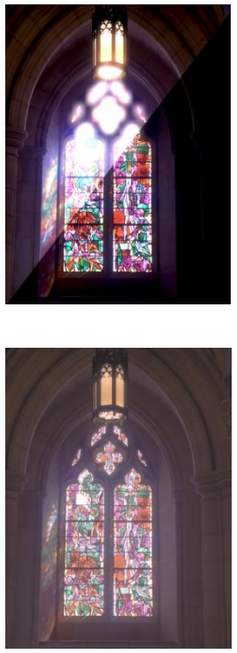
Detection Probability

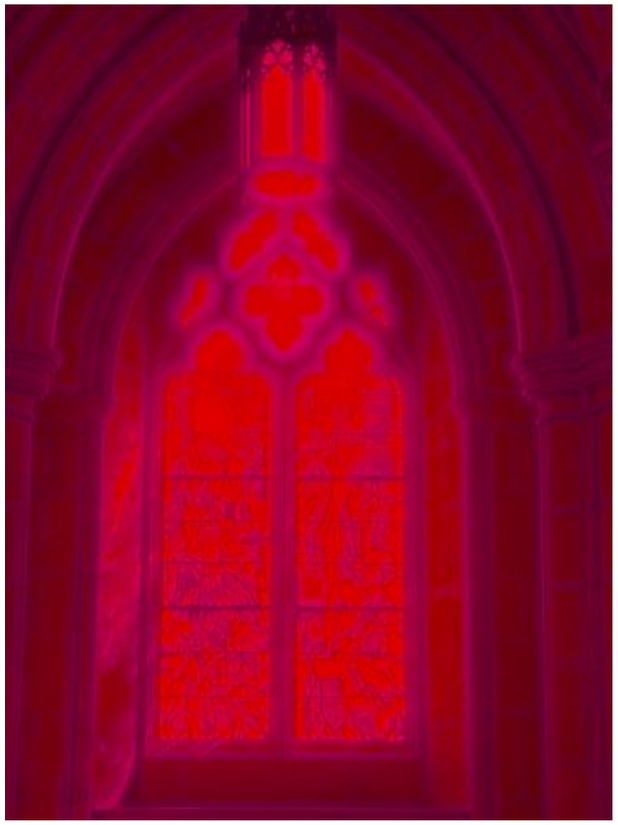
Loss

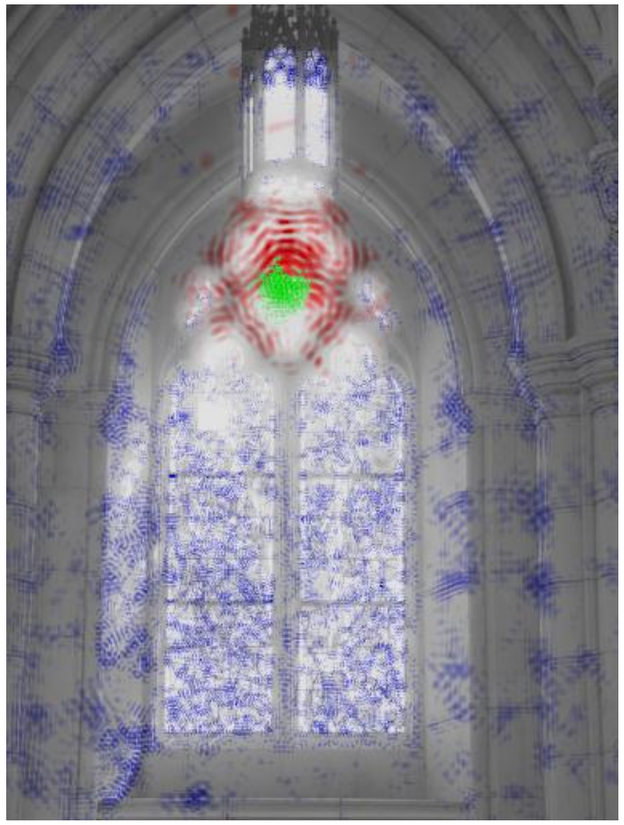
Amplification

Reversal

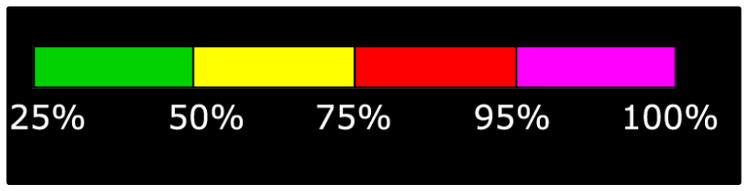
(3) HDR test, LDR reference







HDR-VDP SSIM DRI-IQM



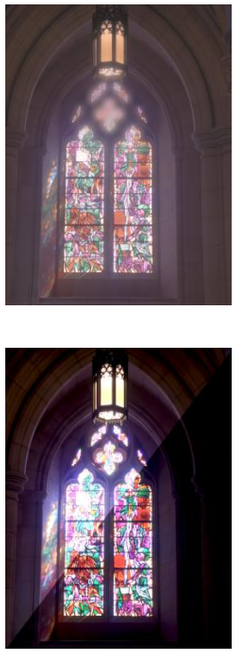
Detection Probability

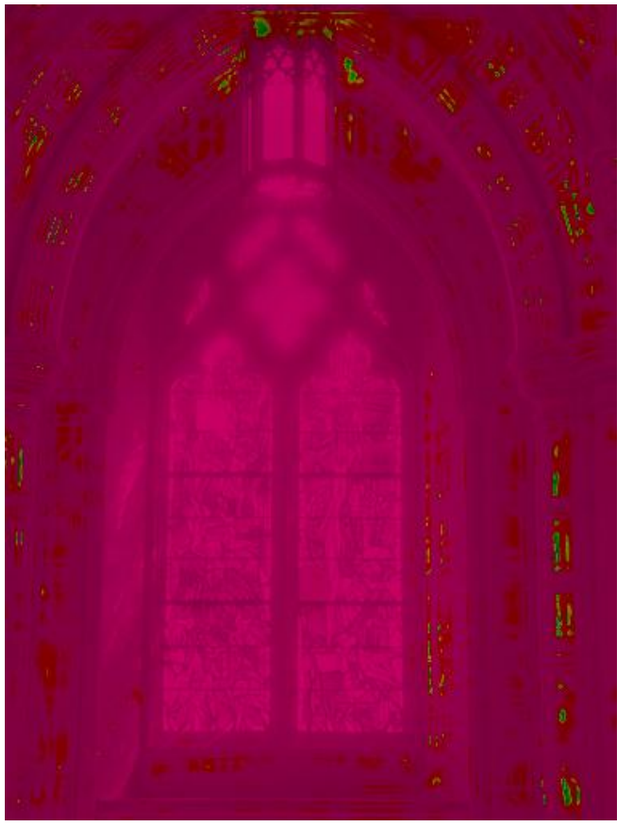
Loss

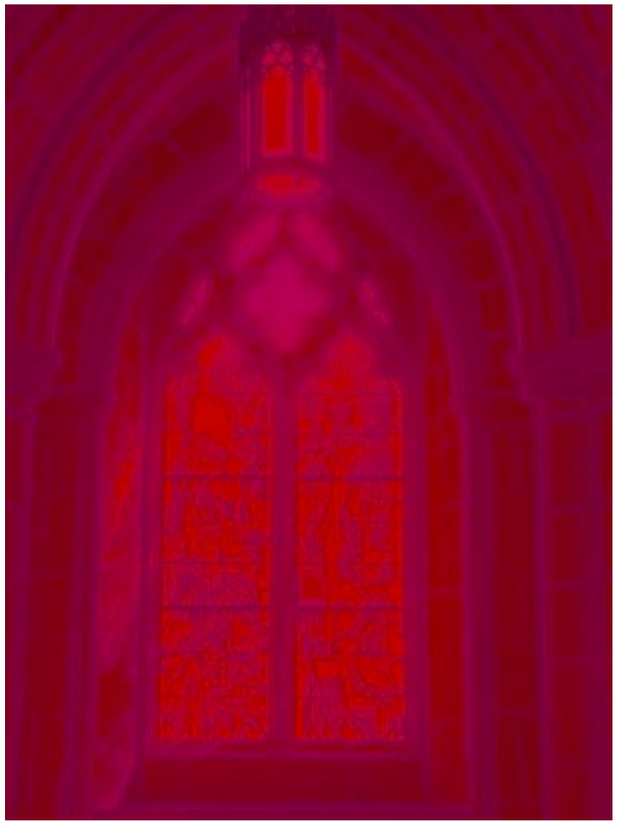
Amplification

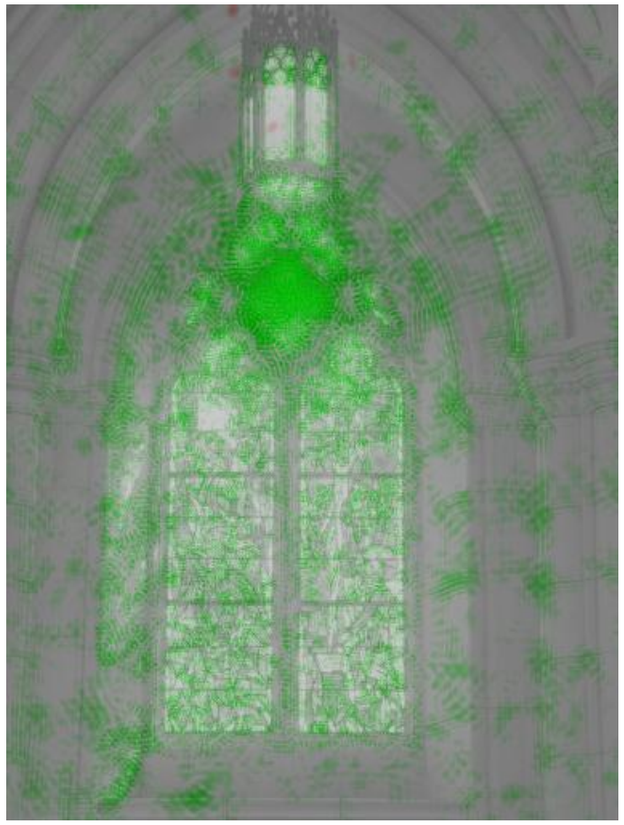
Reversal

(4) LDR test, HDR reference

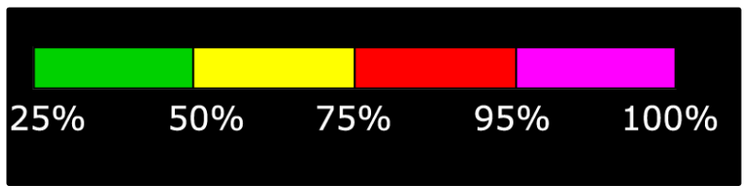








HDR-VDP SSIM DRI-IQM



Detection Probability

Loss

Amplification

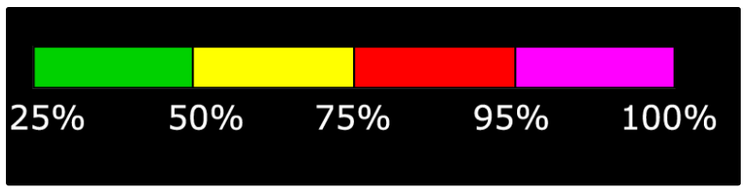
Reversal

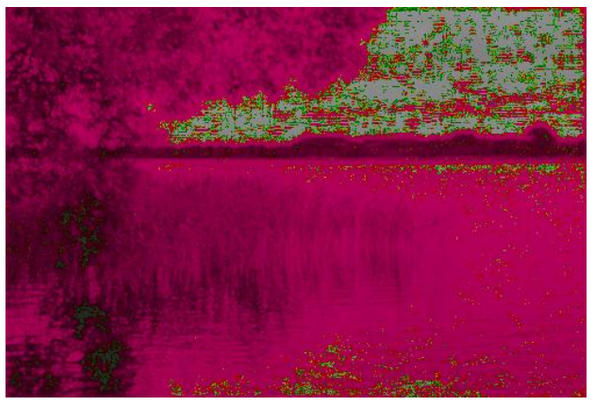
Detecting distortions

Reference

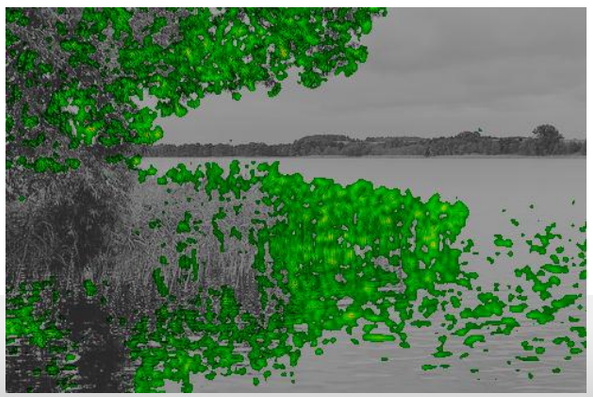
Sharpening

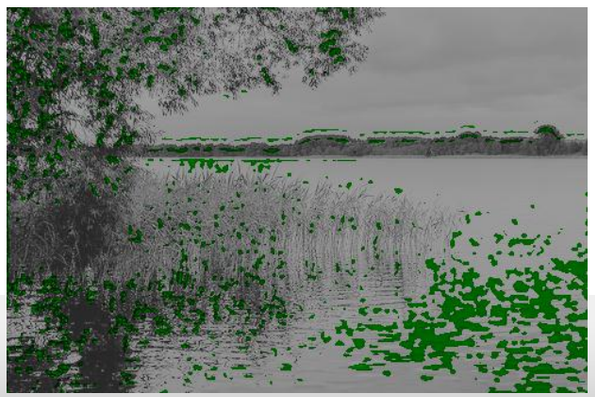
Blur





HDR-VDP





SSIM

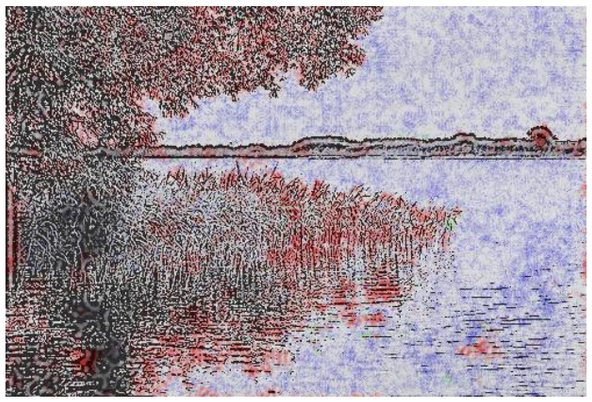
Detecting “types” of distortions

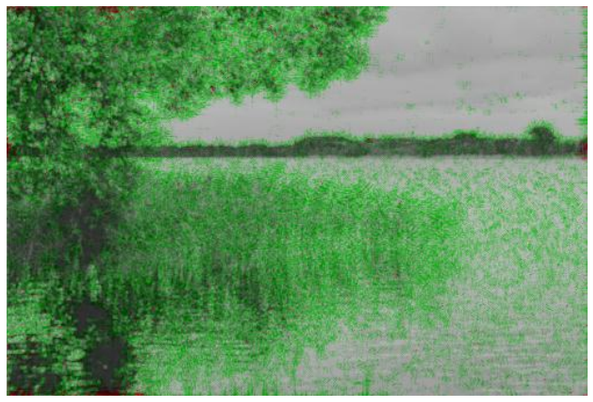
Reference

Sharpening

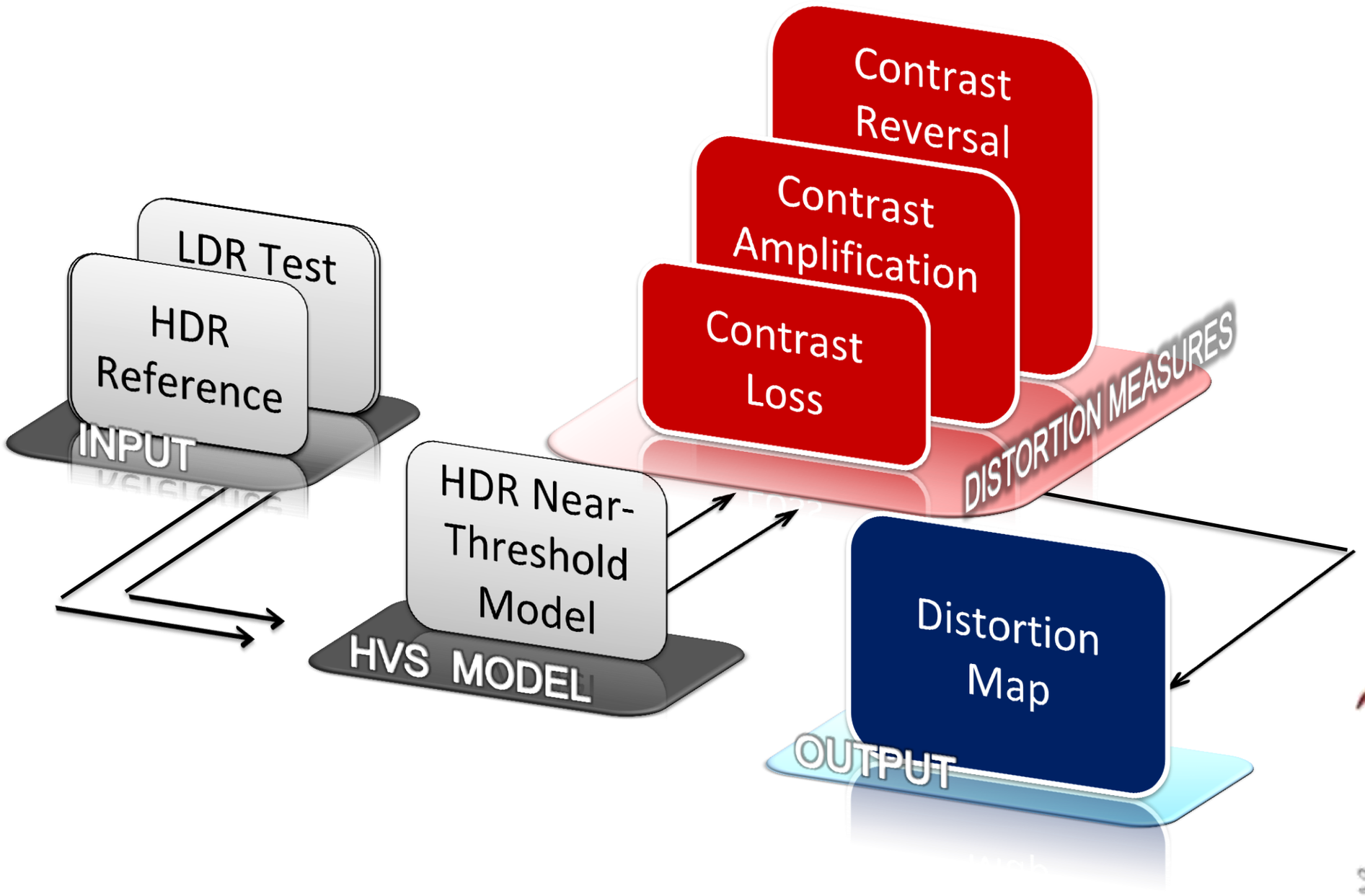
Blur

- Loss
- Amplification
- Reversal



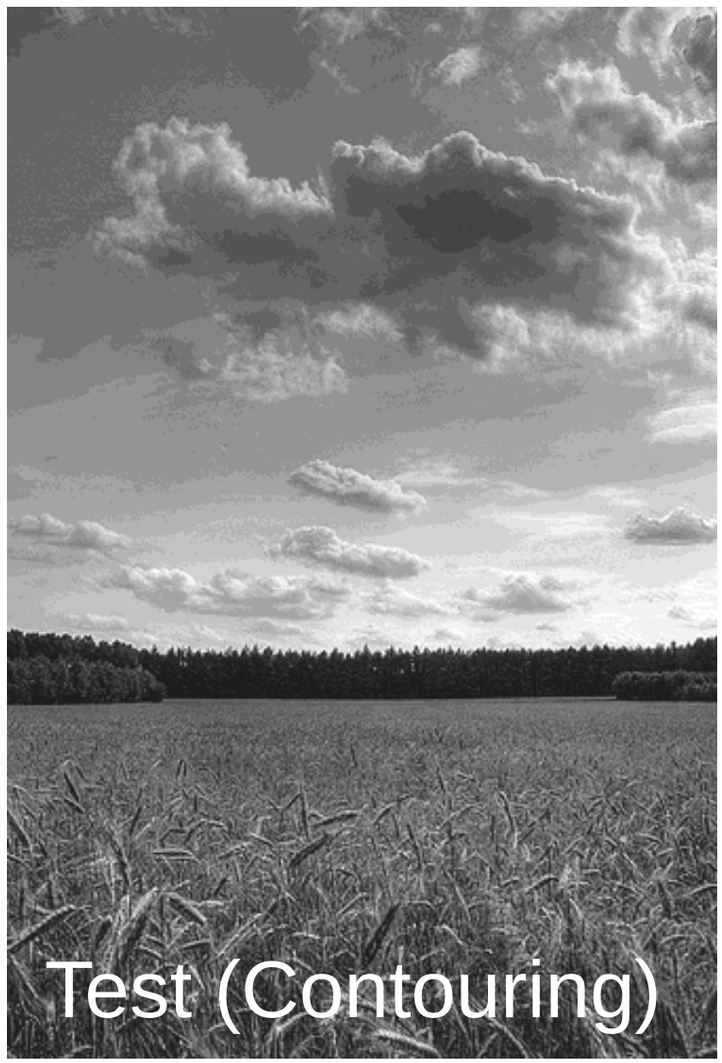


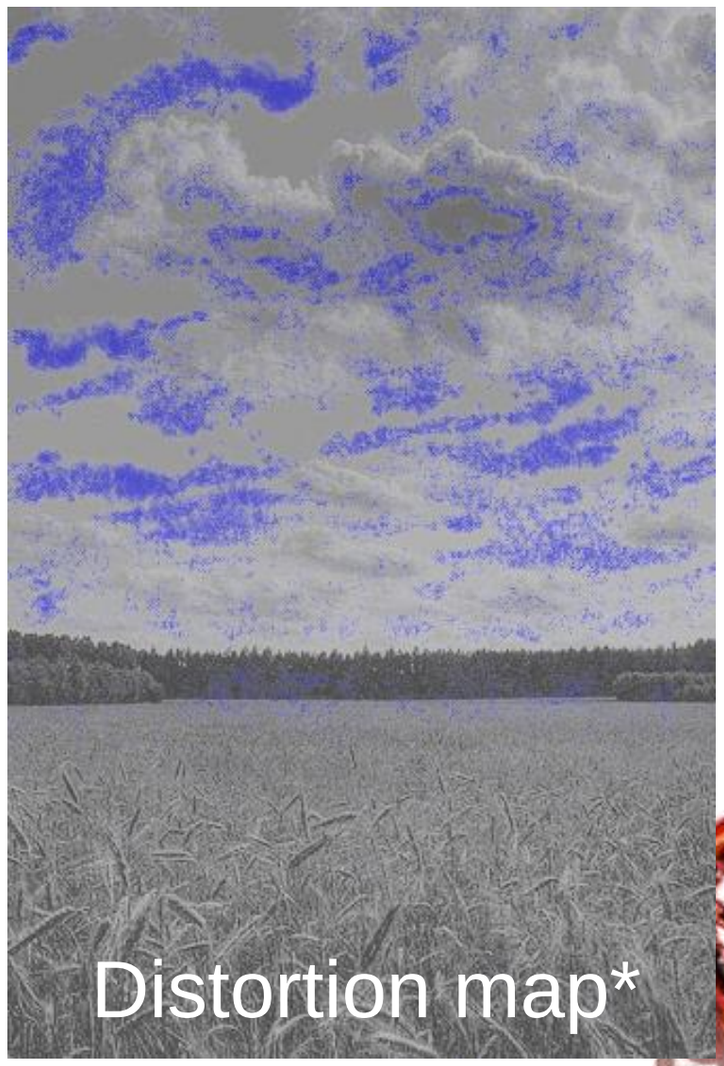
Generic DRI Image Quality Assessment Workflow



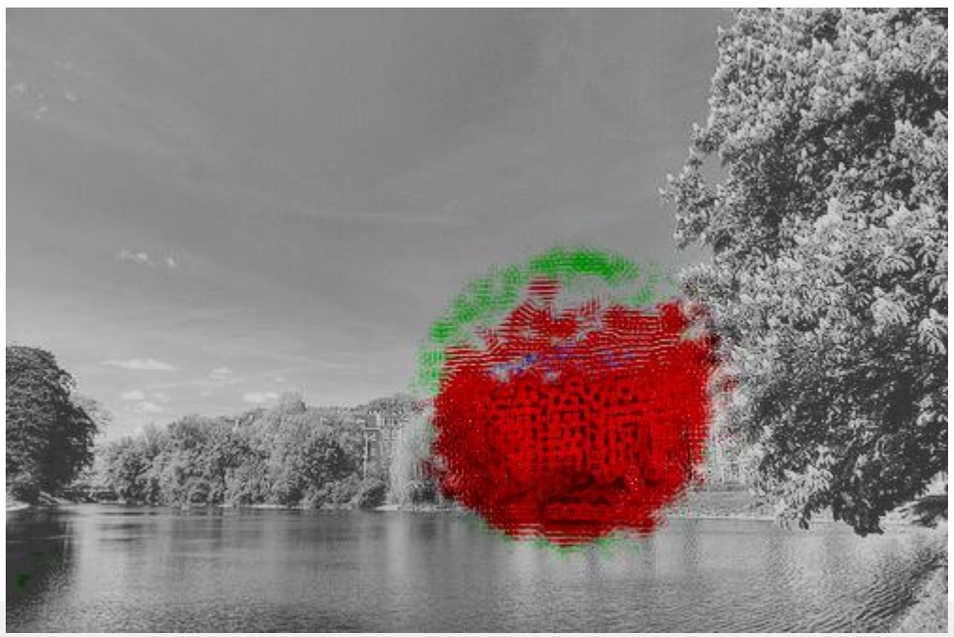
Loss of Visible Contrast

Amplification of Invisible Contrast





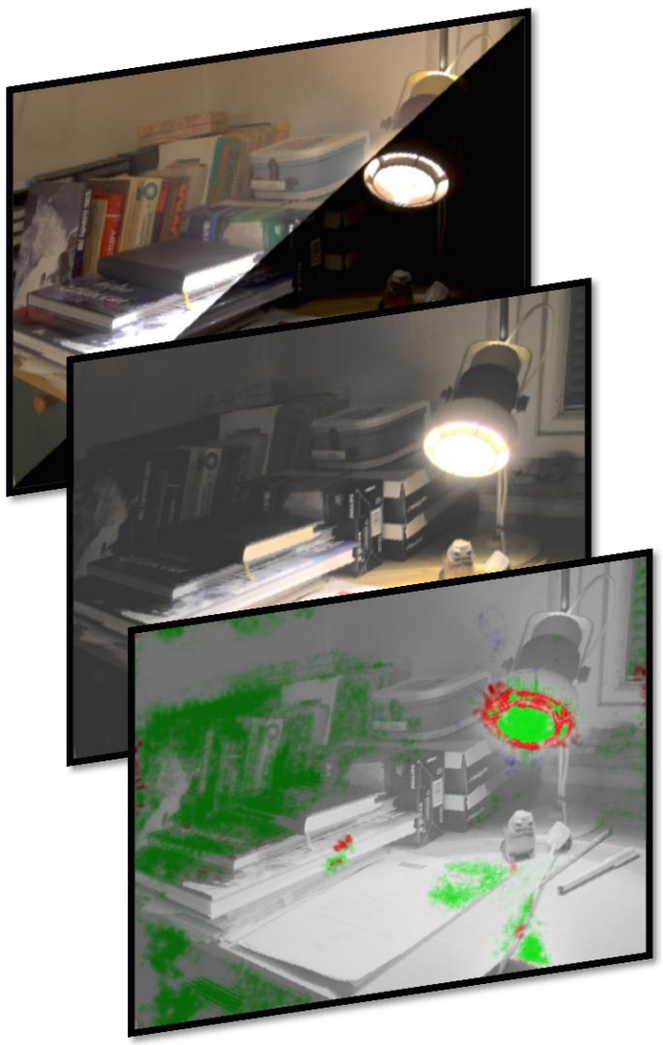
Reversal of Visible Contrast



SIGGRAPHASIA2011 HONG KONG

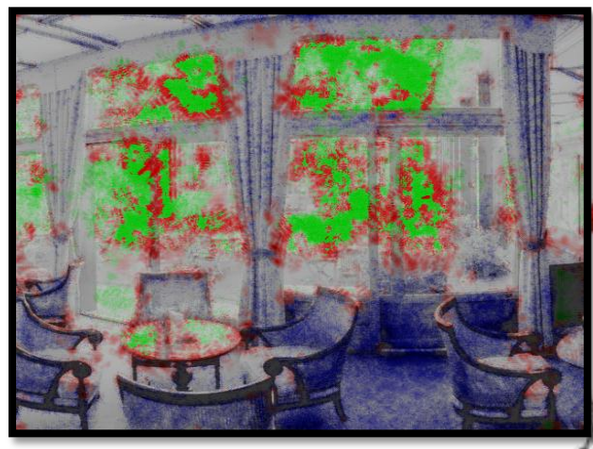
HDR Tone Mapping Evaluation

Tone Mapping

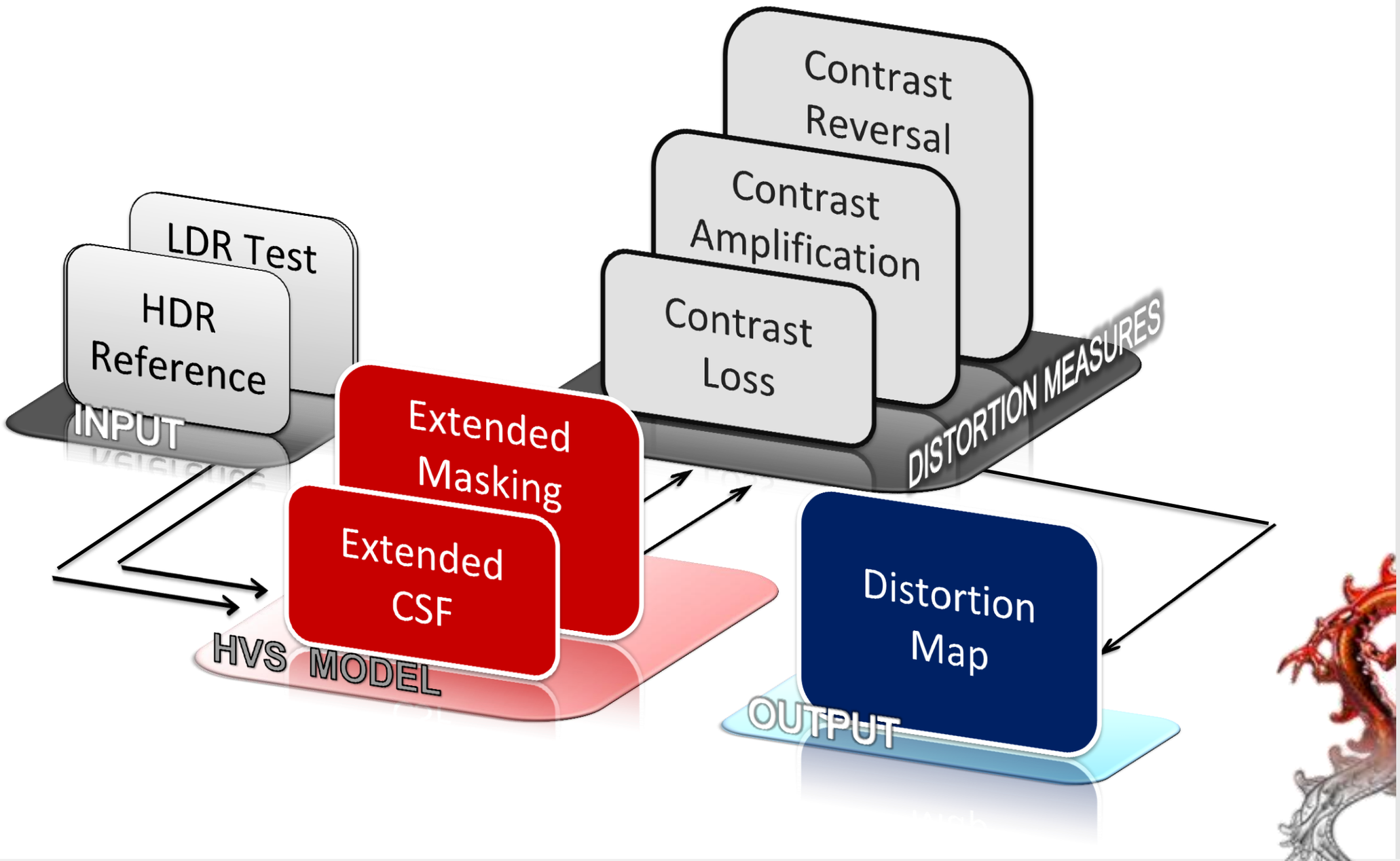


Inverse Tone Mapping

Display Analysis

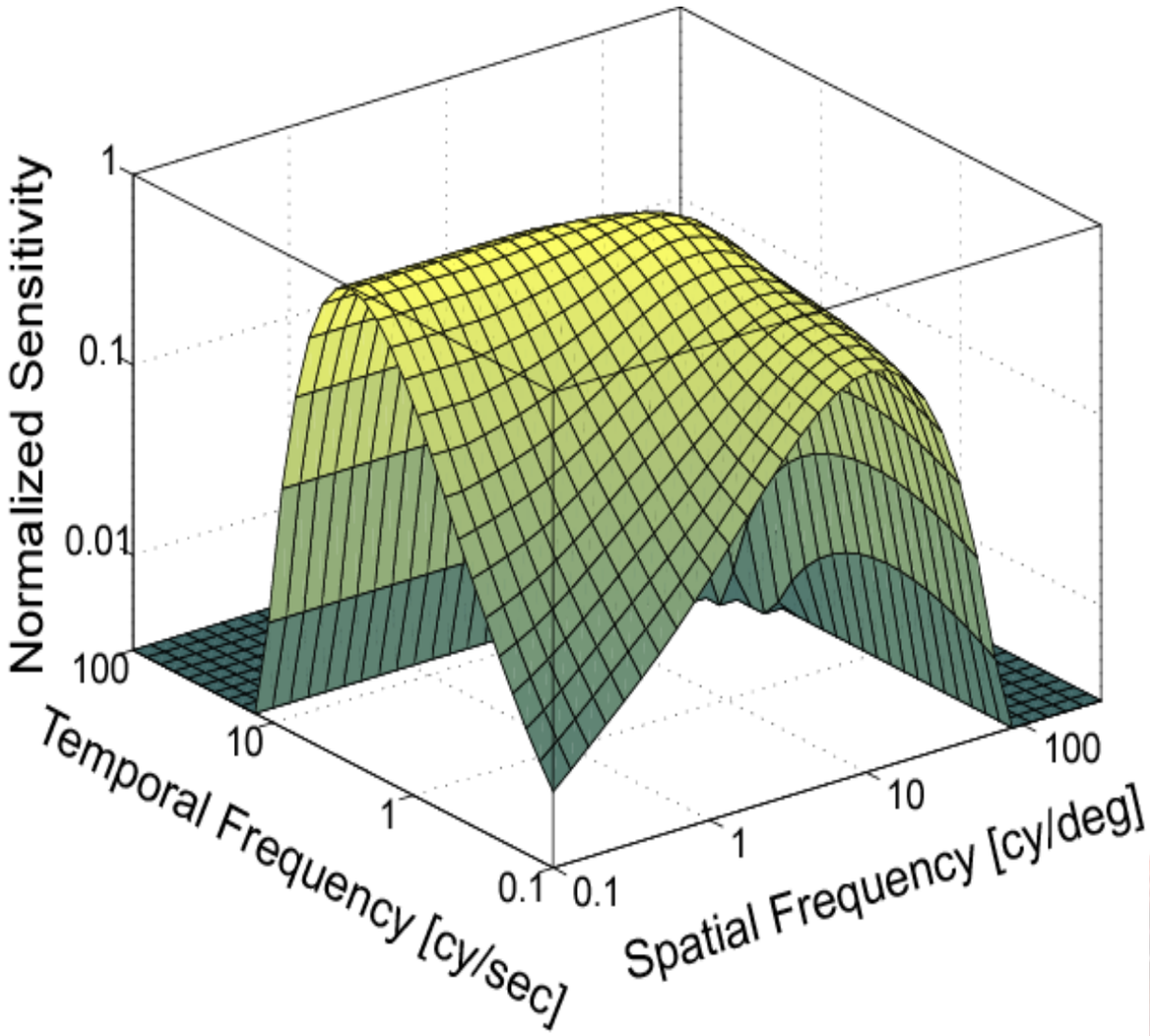


Generic DRI Video Quality Assessment Workflow



Extended Contrast Sensitivity Function

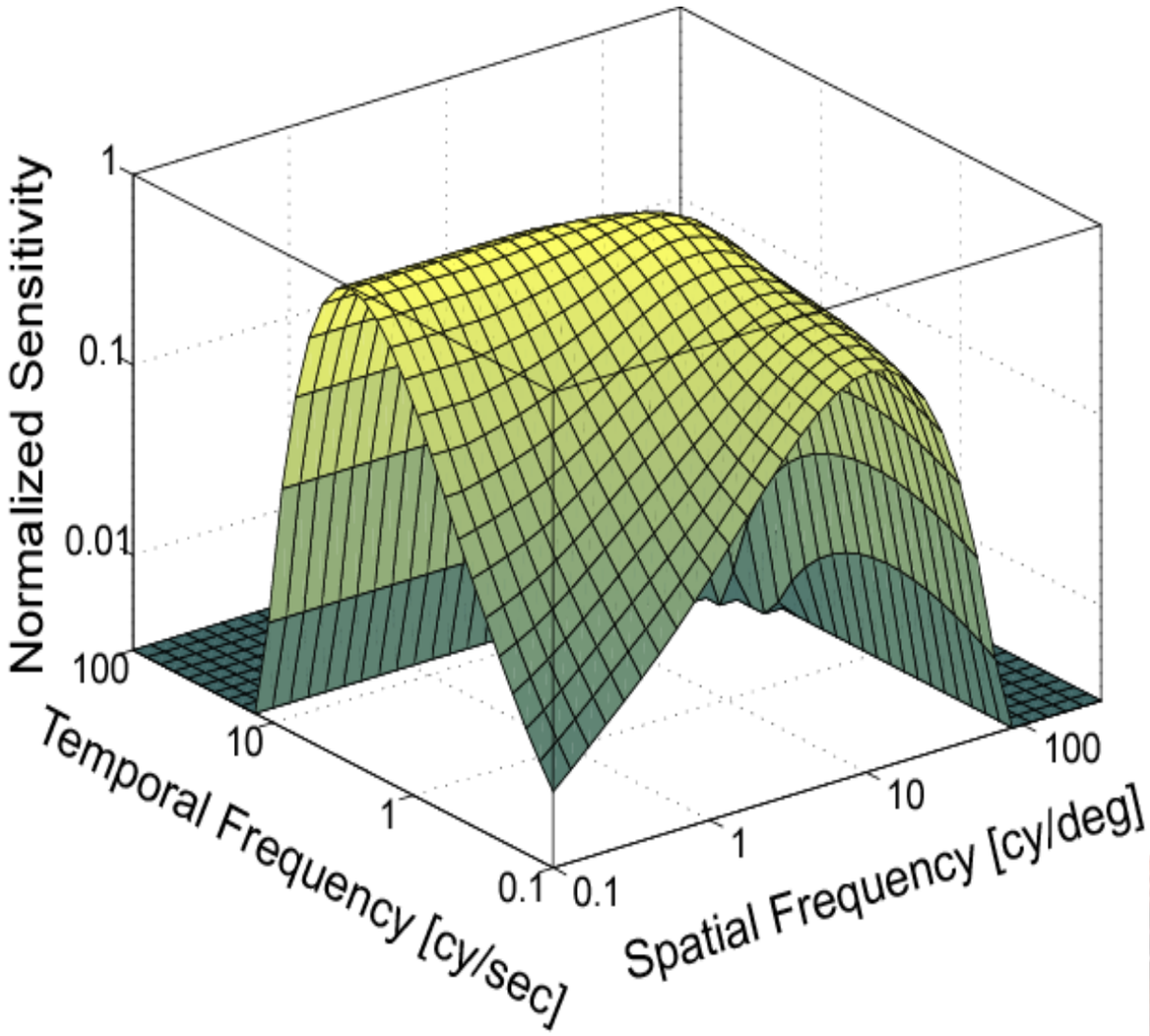
- *CSF:* $\omega, \rho, L_a \rightarrow S$
  - ω*:* temporal frequency,
  - ρ*:* spatial frequency,
  - L_a*:* adaptation level,
  - *S:* sensitivity.



Spatio-temporal CSF

Extended Contrast Sensitivity Function, cont.

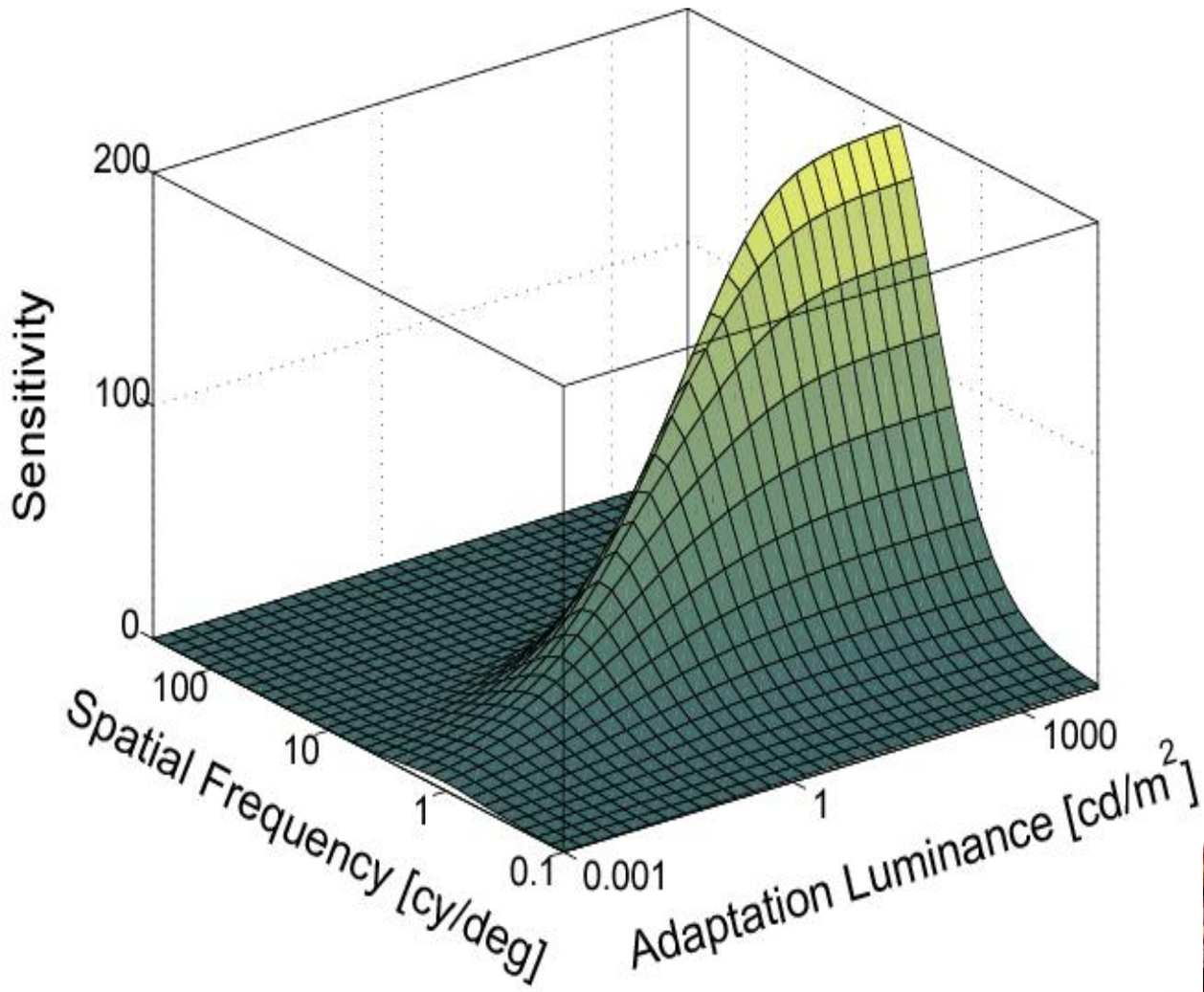
- *CSF:* $\omega, \rho, L_a \rightarrow S$
  - ω*:* temporal frequency,
  - ρ*:* spatial frequency,
  - L_a*:* adaptation level,
  - *S:* sensitivity.



Spatio-temporal CSF^T

Extended Contrast Sensitivity Function, cont.

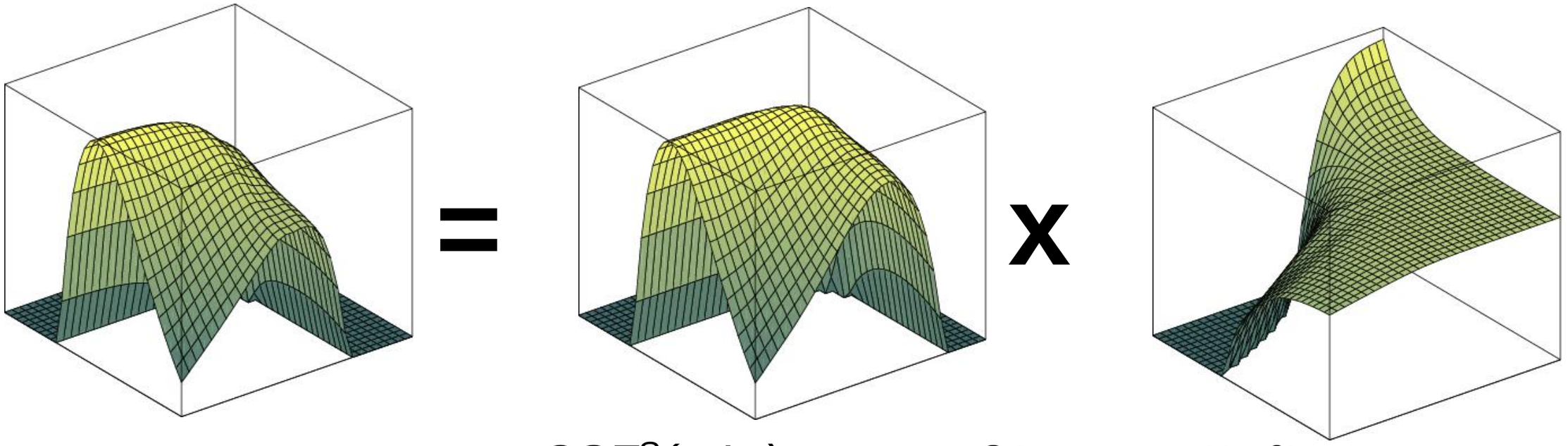
- *CSF:* $\omega, \rho, L_a \rightarrow S$
  - ω*:* temporal frequency,
  - ρ*:* spatial frequency,
  - L_a*:* adaptation level,
  - *S:* sensitivity.



Steady-state CSF^S

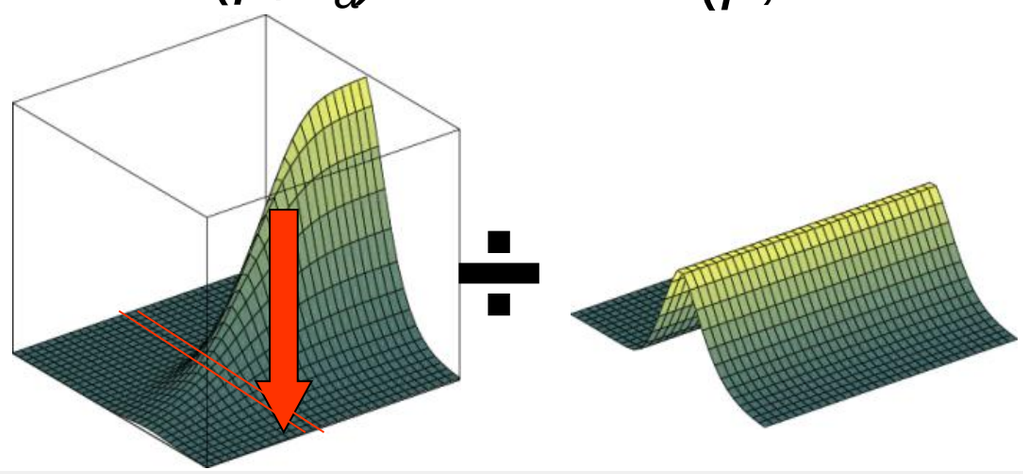
Extended Contrast Sensitivity Function, derivation

$CSF(\omega,\rho,L_a = L)$ $CSF^T(\omega,\rho,L_a = 100\ cd/m^2)$ $f(\rho,L_a)$



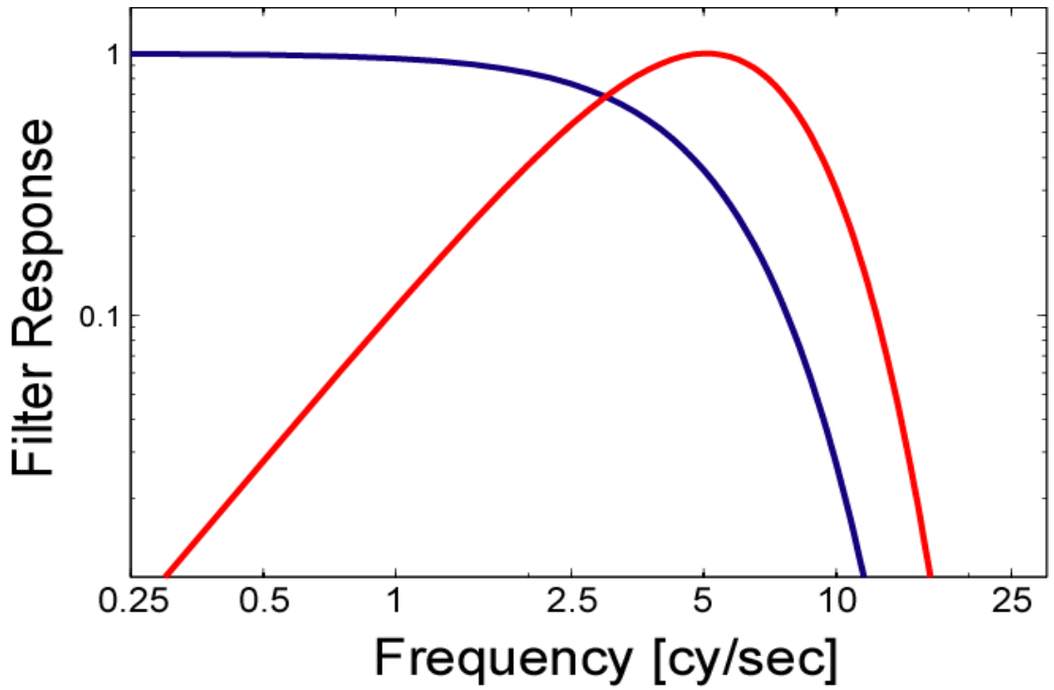
$CSF^S(\rho,L_a)$ $CSF^S(\rho,100\ cd/m^2)$

$$f = \left(\div \right)$$

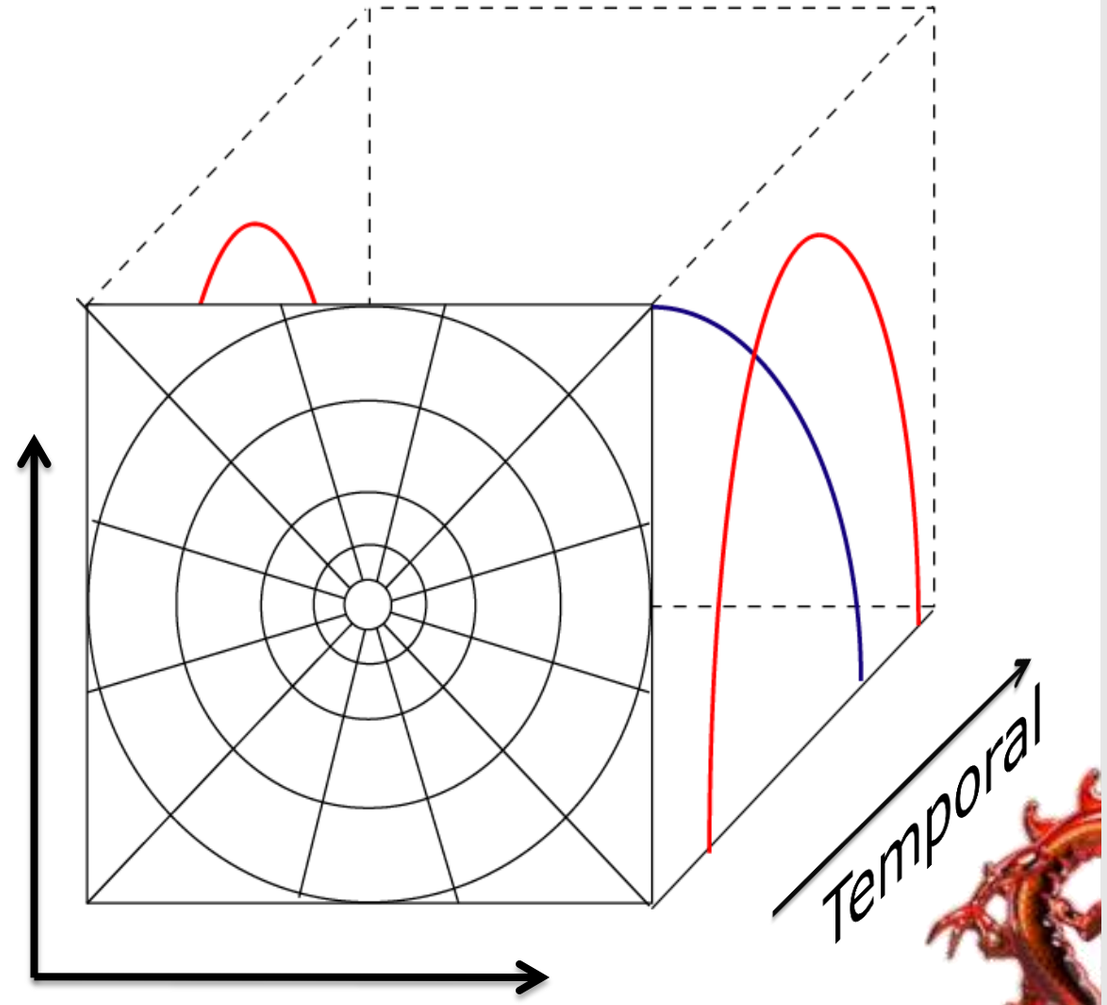


$L_a = 100\ cd/m^2$

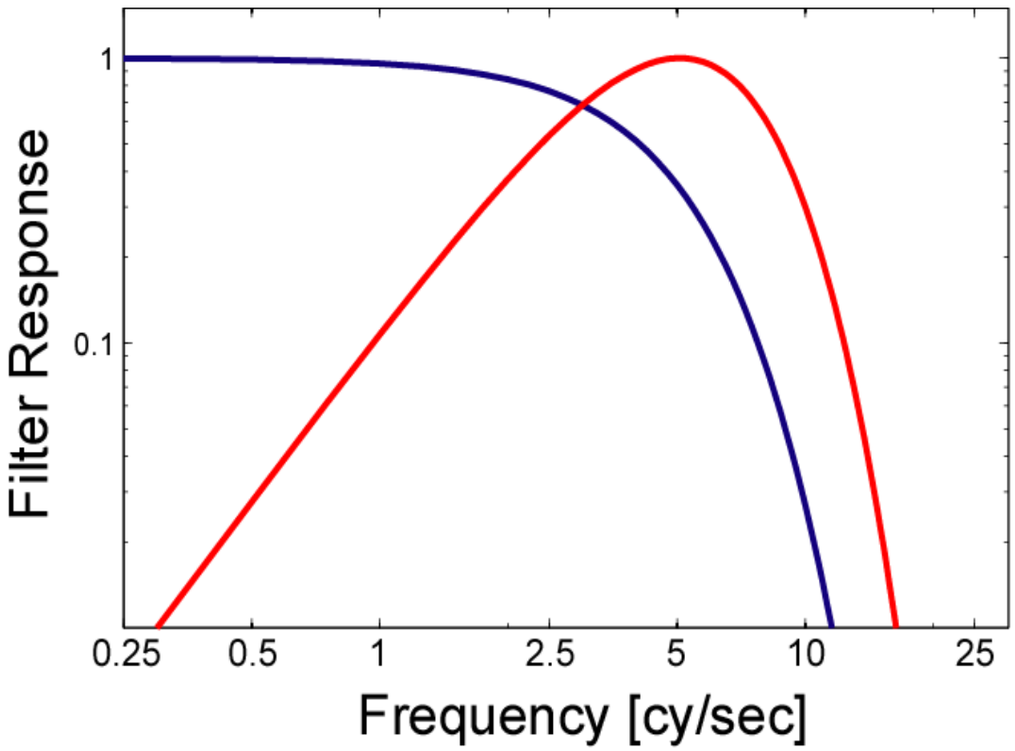
Extended Cortex Transform



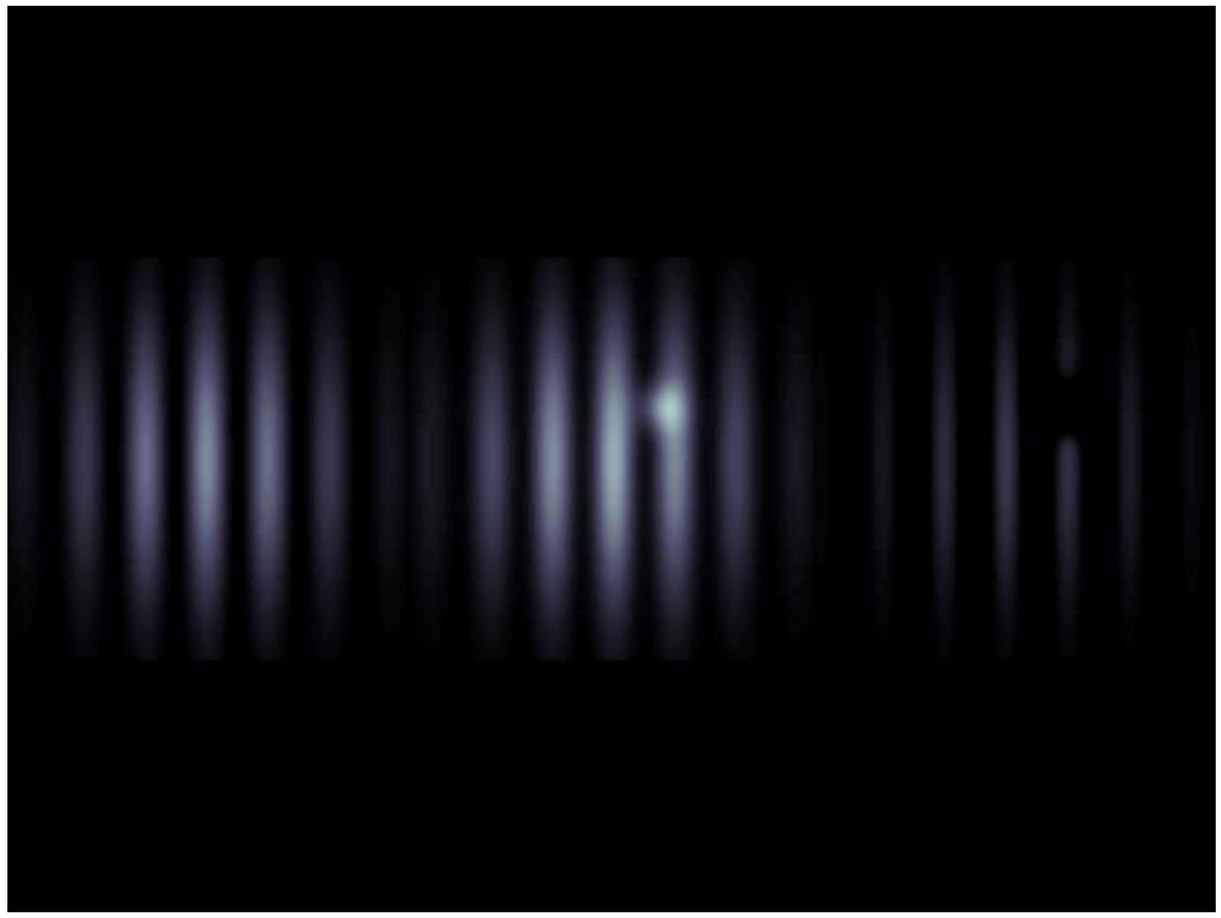
Sustained and **Transient**
Temporal Channels [Winkler 2005]



Temporal Channels



Sustained and **Transient**
Temporal Channels

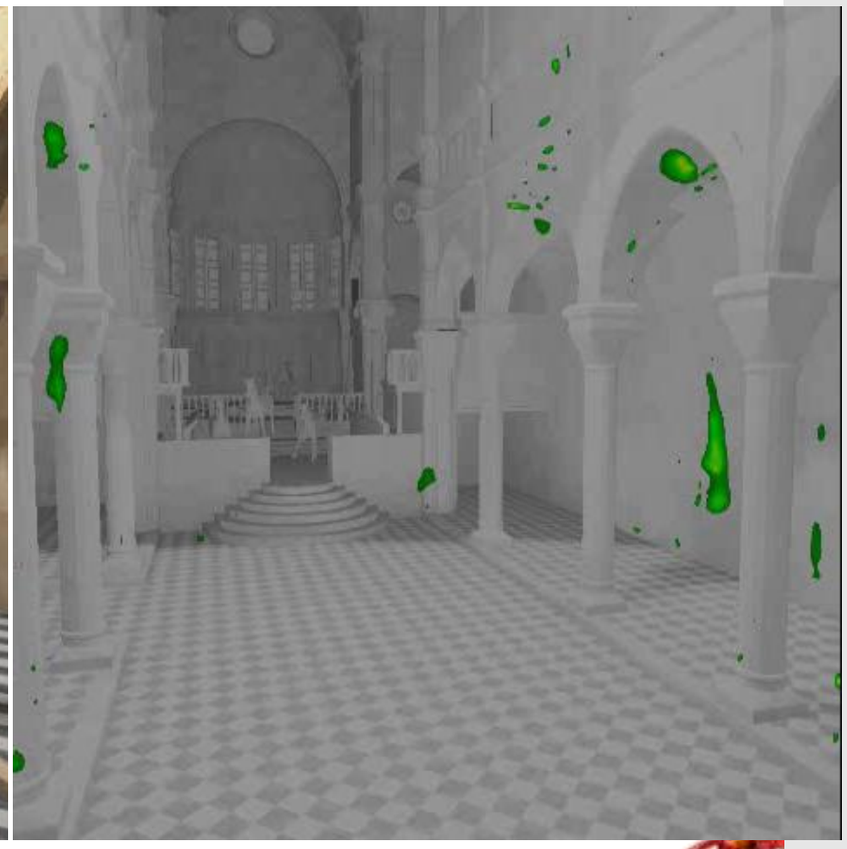


Signal **Sustained** **Transient**

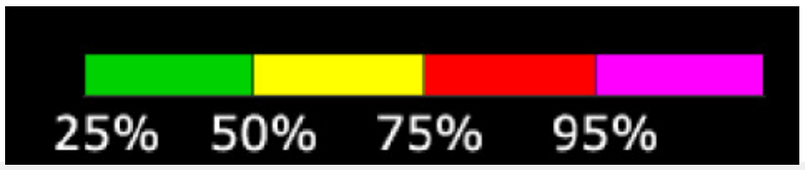
Evaluation of Rendering Methods

With temporal filtering [Herzog et al. 2010]

No temporal filtering

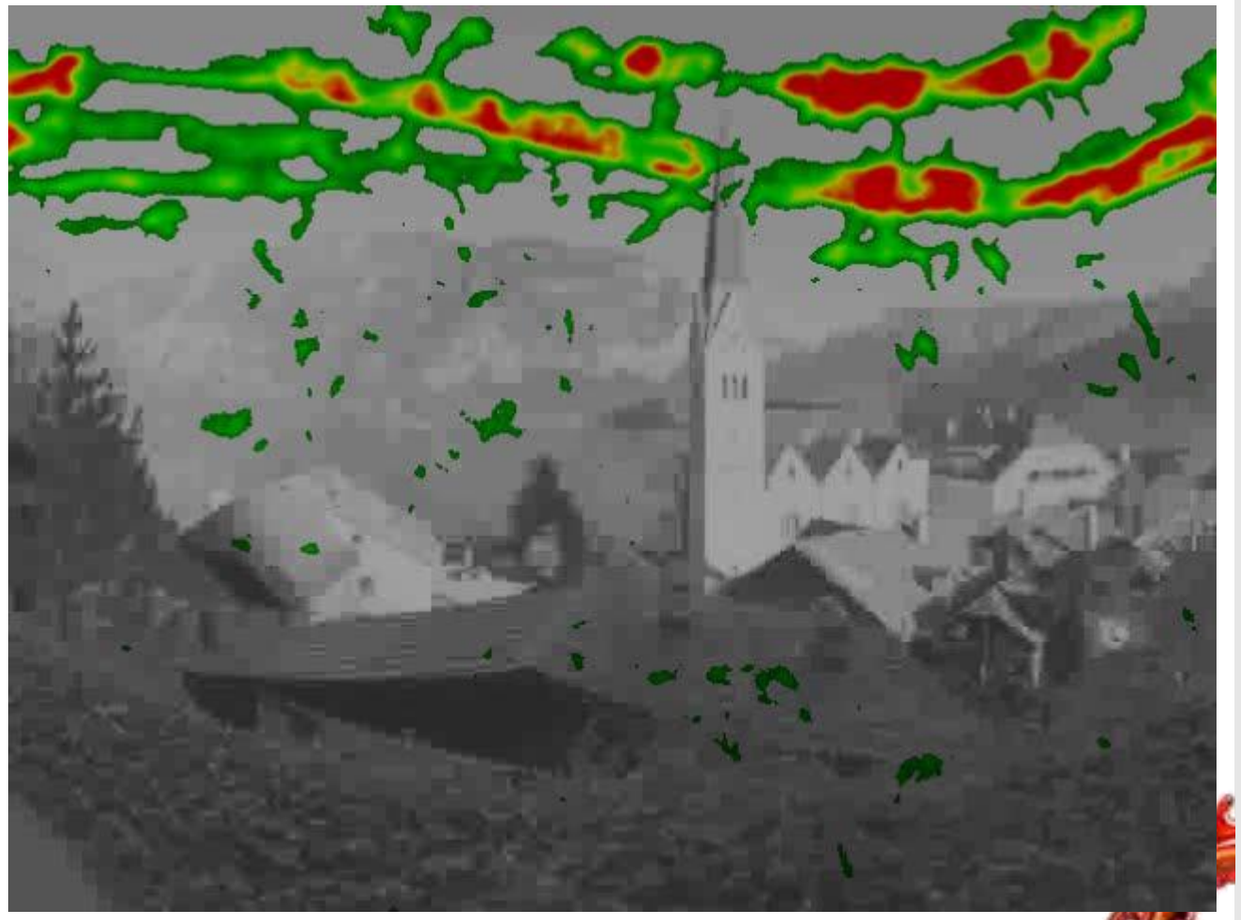


Predicted distortion map

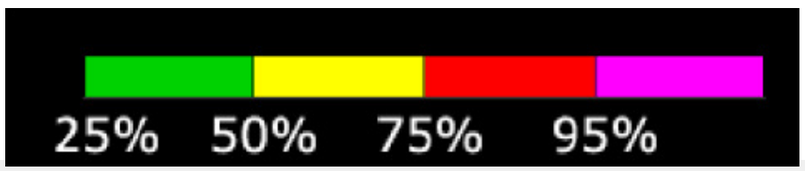


Evaluation of HDR Compression

Medium Compression

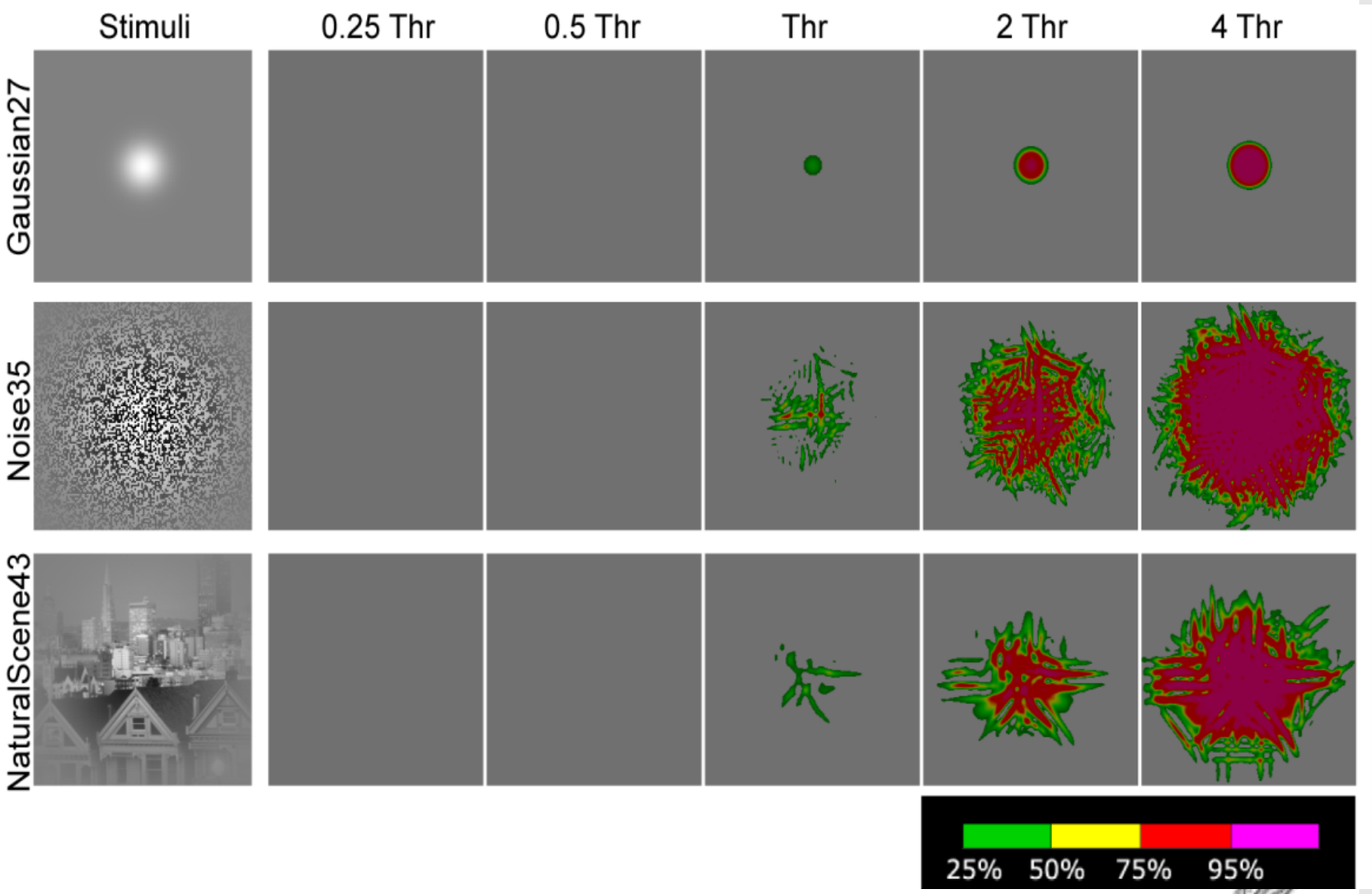


High Compression



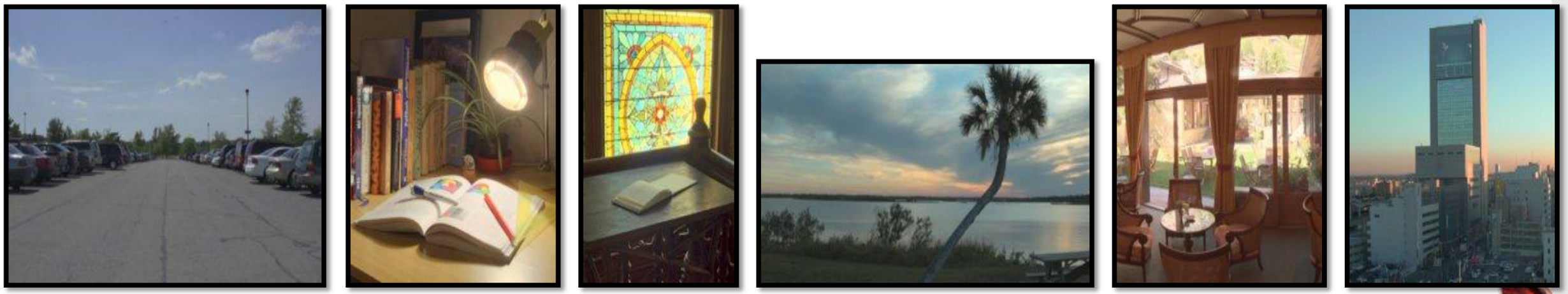
Subjective Calibration

- Modelfest dataset at five contrast levels



Subjective Validation

- Example [Aydın et al. 2010, Čadík et al. 2010]
- Noise, HDR video compression, tone mapping
- “2.5D videos”
- LDR-LDR, HDR-HDR, HDR-LDR

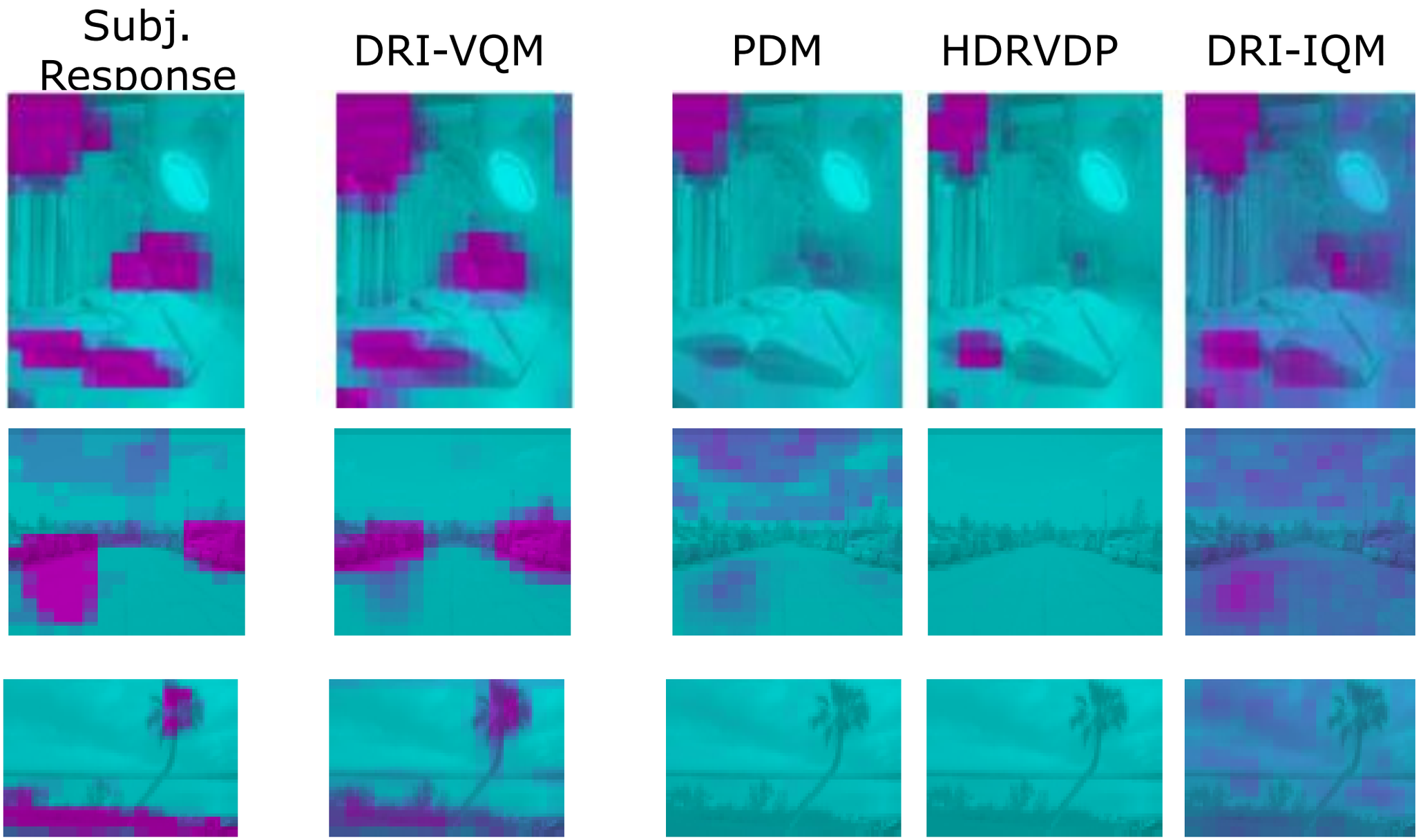


Subjective Validation, cont.

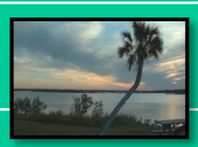
(1) Show videos side-by-side on a HDR Display

(2) Subjects mark regions where they detect differences

Subjective vs. Objective Results



Subjective Validation, cont.

Stimulus	DRI-VQM	PDM	HDRVDP	DRIVDP
1 	0.765	-0.0147	0.591	0.488
2 	0.883	0.686	0.673	0.859
3 	0.843	0.886	0.0769	0.865
4 	0.815	0.0205	0.211	-0.0654
5 	0.844	0.565	0.803	0.689
6 	0.761	-0.462	0.709	0.299
7 	0.879	0.155	0.882	0.924
8 	0.733	0.109	0.339	0.393
9 	0.753	0.368	0.473	0.617
Average	0.809	0.257	0.528	0.563

- [Čadík et al. 2010] Data available at: http://www.mpi-inf.mpg.de/resources/hdr/quality

Conclusions

- A number of established metrics are available as source code or web service
  - SSIM: https://ece.uwaterloo.ca/~z70wang/research/ssim/
  - HDRVDP : http://sourceforge.net/projects/hdrvdp/files/hdrvdp/
  - DRI-IQM and DRI-VQM:

    http://drim.mpi-inf.mpg.de/
- Researchers are starting using these metrics instead of user studies.
- Future directions:
  - Metrics for retargeted images [Liu et al. 2011]
  - Better HVS models [Mantiuk et al. 2011]
  - Smarter distortion measures.