Visual perception in Visualization

1 Visual Perception: Motivation, basic facts

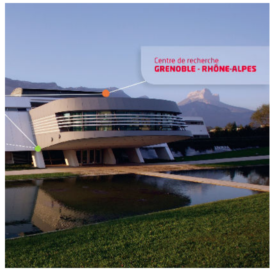
2 Perception of Depth – Application to DVR evaluation

3 Perception of Noise – Application to Uncertainty Vis.

4 Perception of Shape – Application to Image manipulation

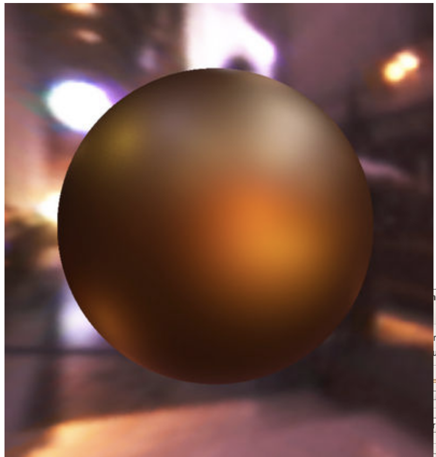
Georges-Pierre Bonneau, Laboratoire Jean Kuntzmann, UGA, G-INP & INRIA Grenoble

Background

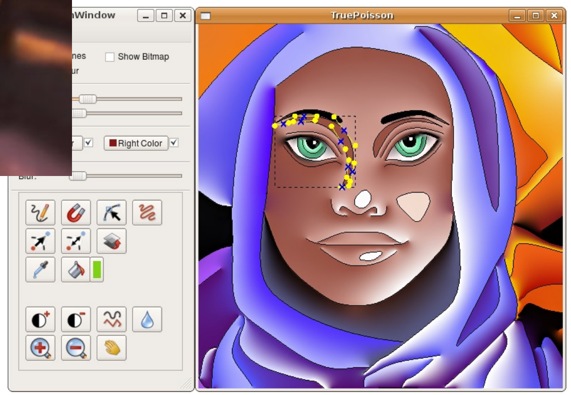


Team MAVERICK at LJK, University of Grenoble (LJK) & INRIA Grenoble

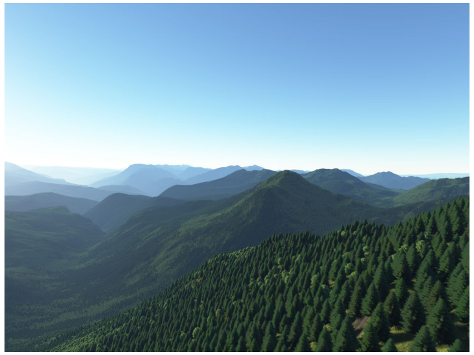
Realistic rendering



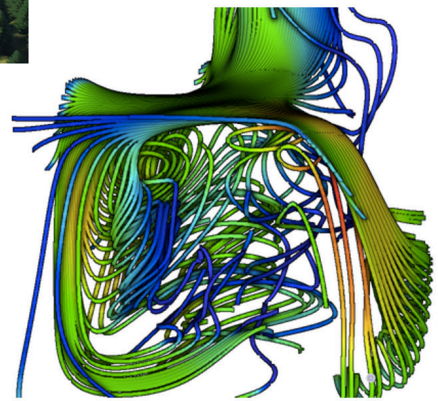
Expressive rendering



Complex scenes



Visualization



Advancing fronts in SciVi

- Theoretical approaches:
    - Specific scientific domain
    - Multiresolution
    - Topology
        - EuroVis2017, Giri Nucha (IISc), G.-P. Bonneau & al.
        - Computing Contour Tree for Higher Order Polynomials

- Visual Perception and Cognition awareness in Visualization

Visual Perception

motivation, basic facts

1

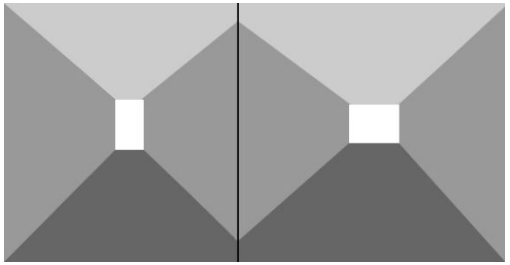
Motivation

http://nivea.psycho.univ-paris5.fr/

Visual Perception

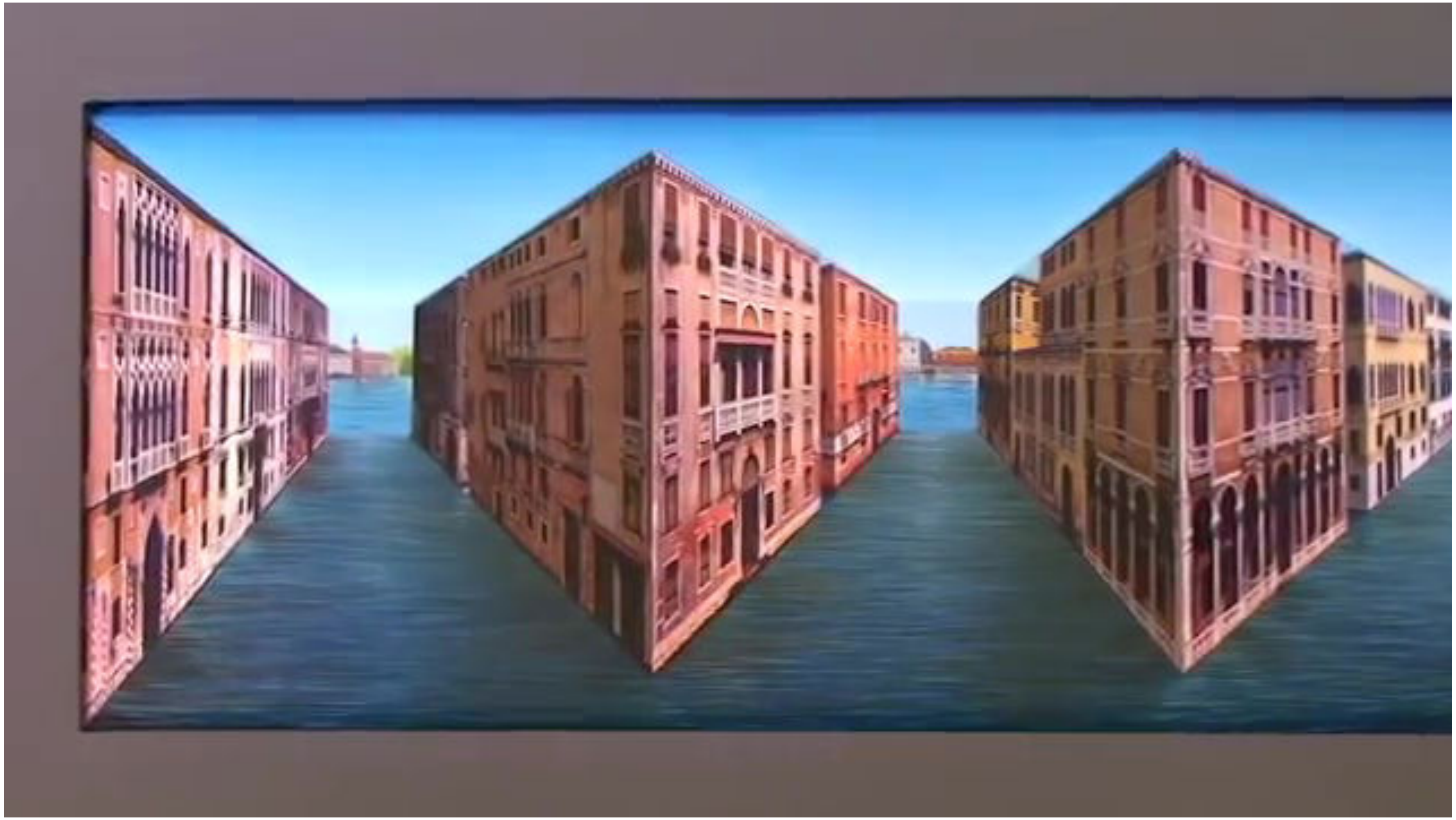
Perception is the organization, identification and interpretation of sensory information in order to represent and understand the environment.

« Perceiving is identify something somewhere, and this need for localized identification persists even when we look at some abstract configurations, for which we cannot build on any previous experience » (Gombrich, in *Art and Illusion*)



Reverspective
http://www.patrickhughes.co.uk/

Reverspective

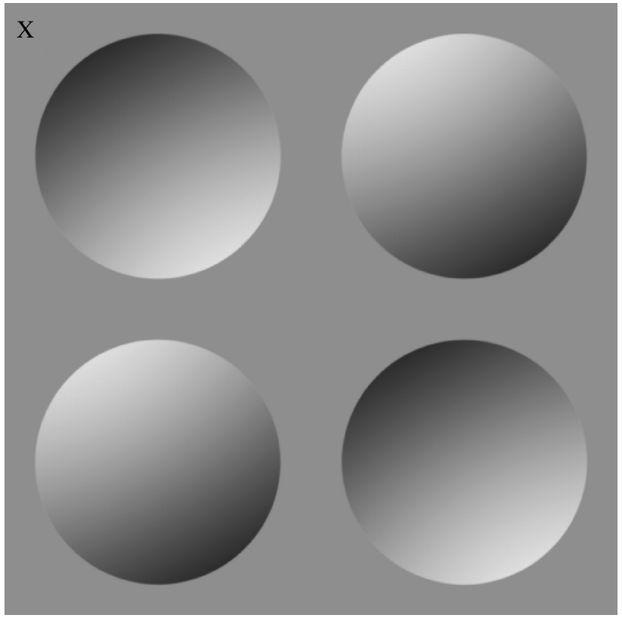


http://www.patrickhughes.co.uk/

A priori in Visual perception

http://michaelbach.de/

A priori in Visual perception



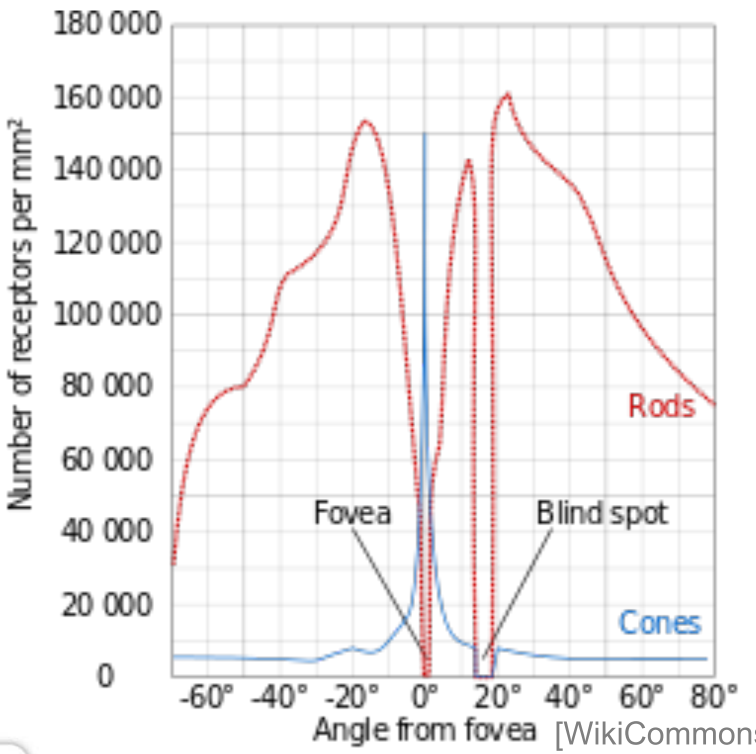
[Stone&al.,2009]

Basic Vision, pp. 226

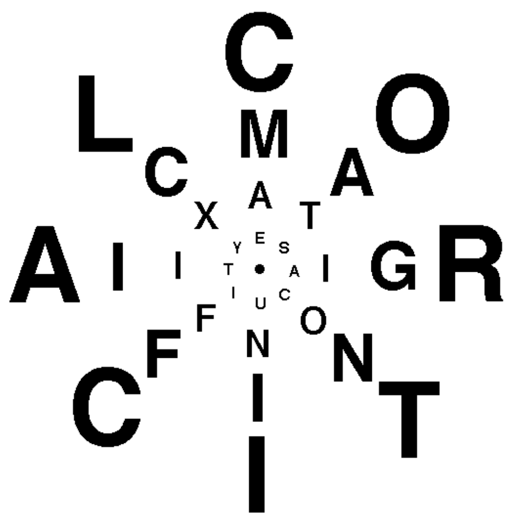
Visual Acuity

Contrast: 120 millions rodes

Color: 5 millions cones



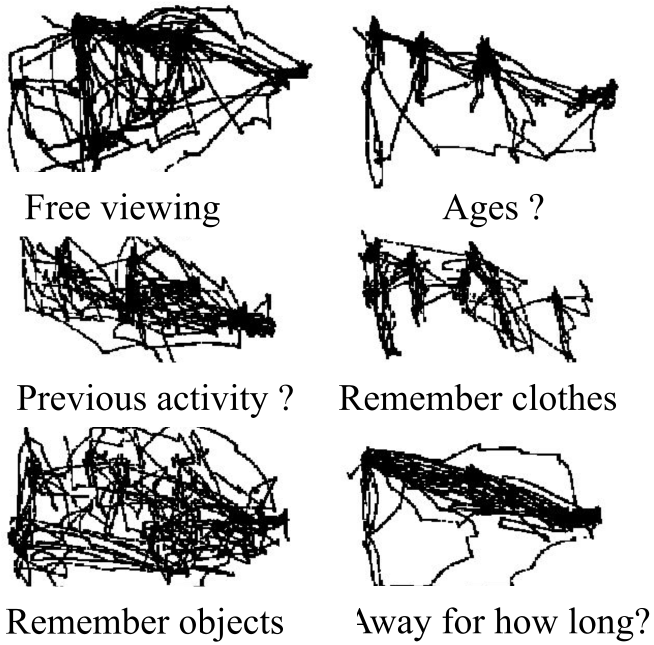
[WikiCommons CC BY_SA 3.0]



Anstis, S. (1974).

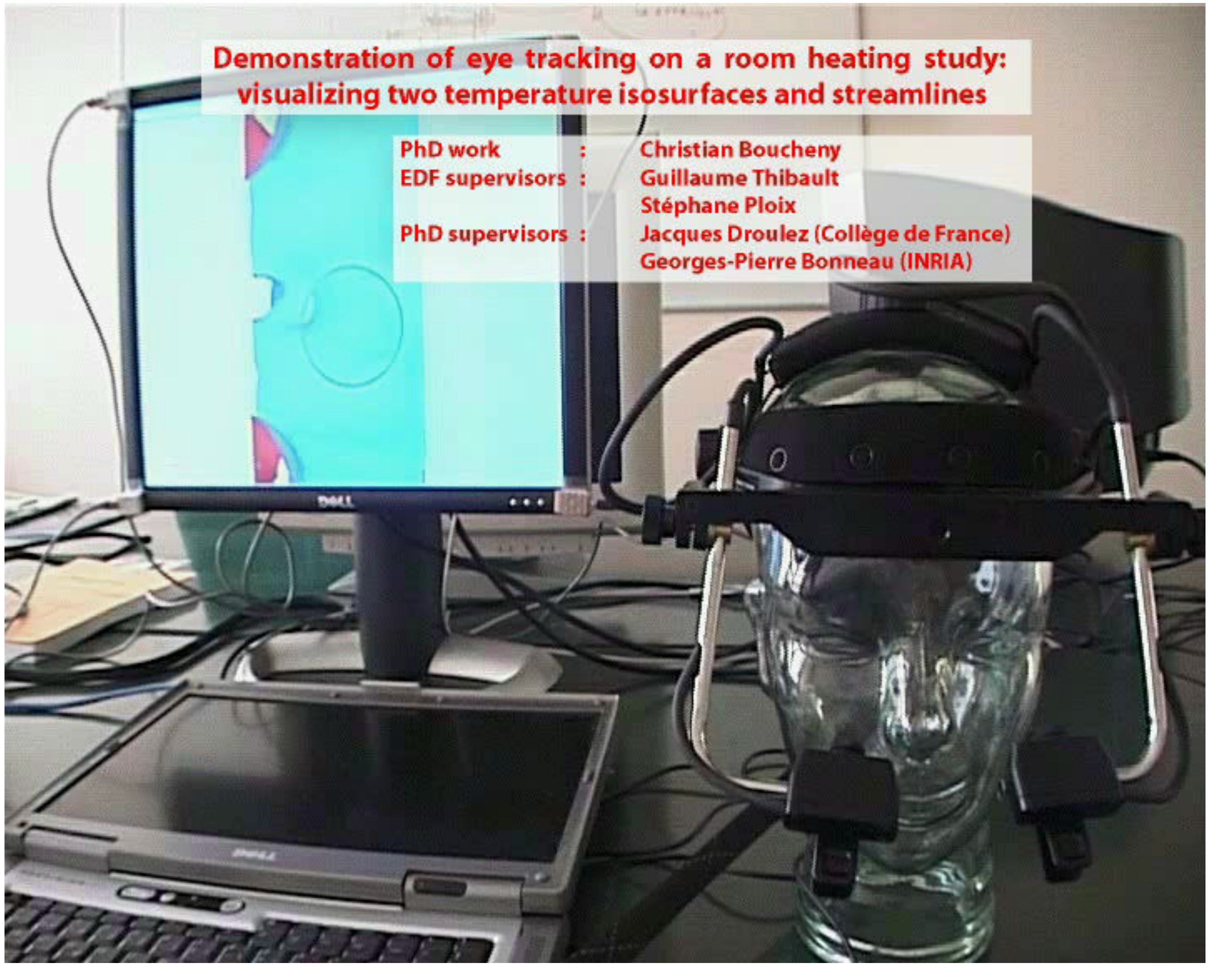
Saccadic eye movements

I. E. Repin, *Un visiteur inattendu* (1884)



Yarbus, Eye movement and Vision, 1967, fig. 109

Gaze guided visualization



Depth perception

In Direct Volume Rendering

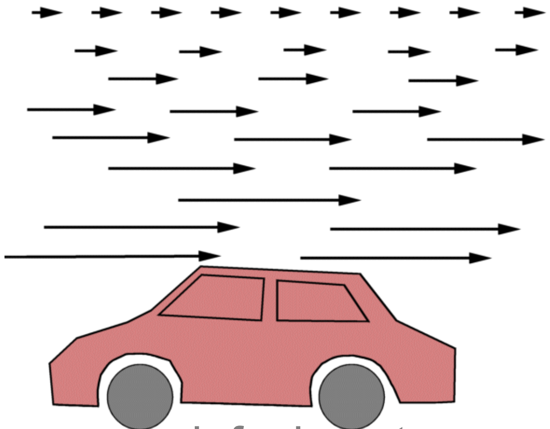
2

Depth perception


wikipedia

Ten monocular cues

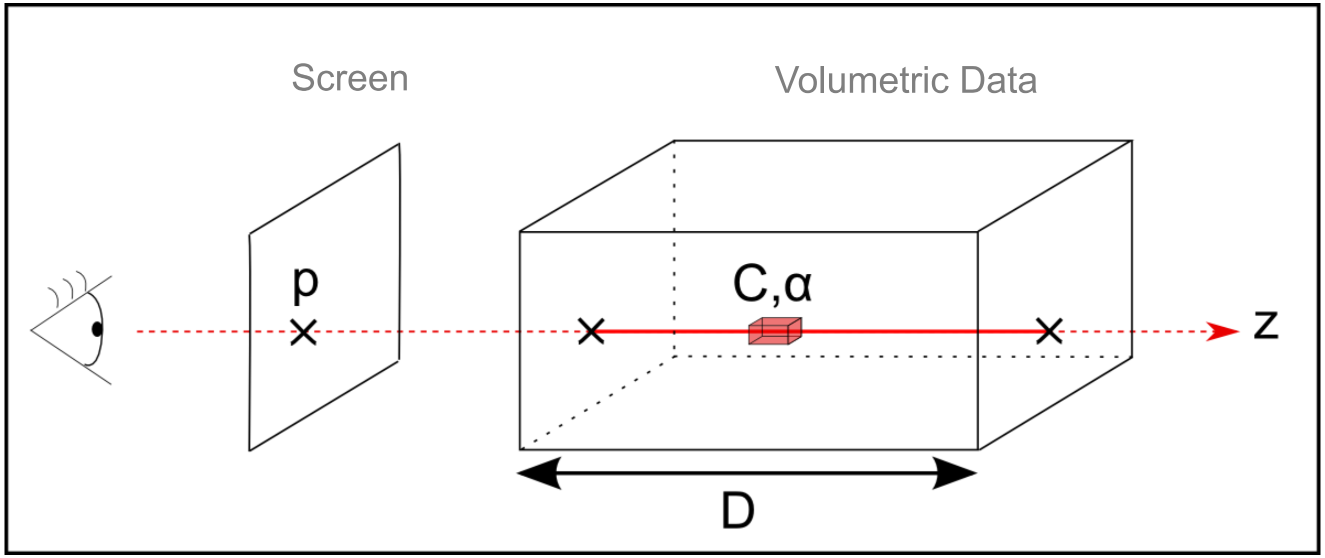
Two binocular cues


www.infovis.net


wikipedia

Direct Volume Rendering

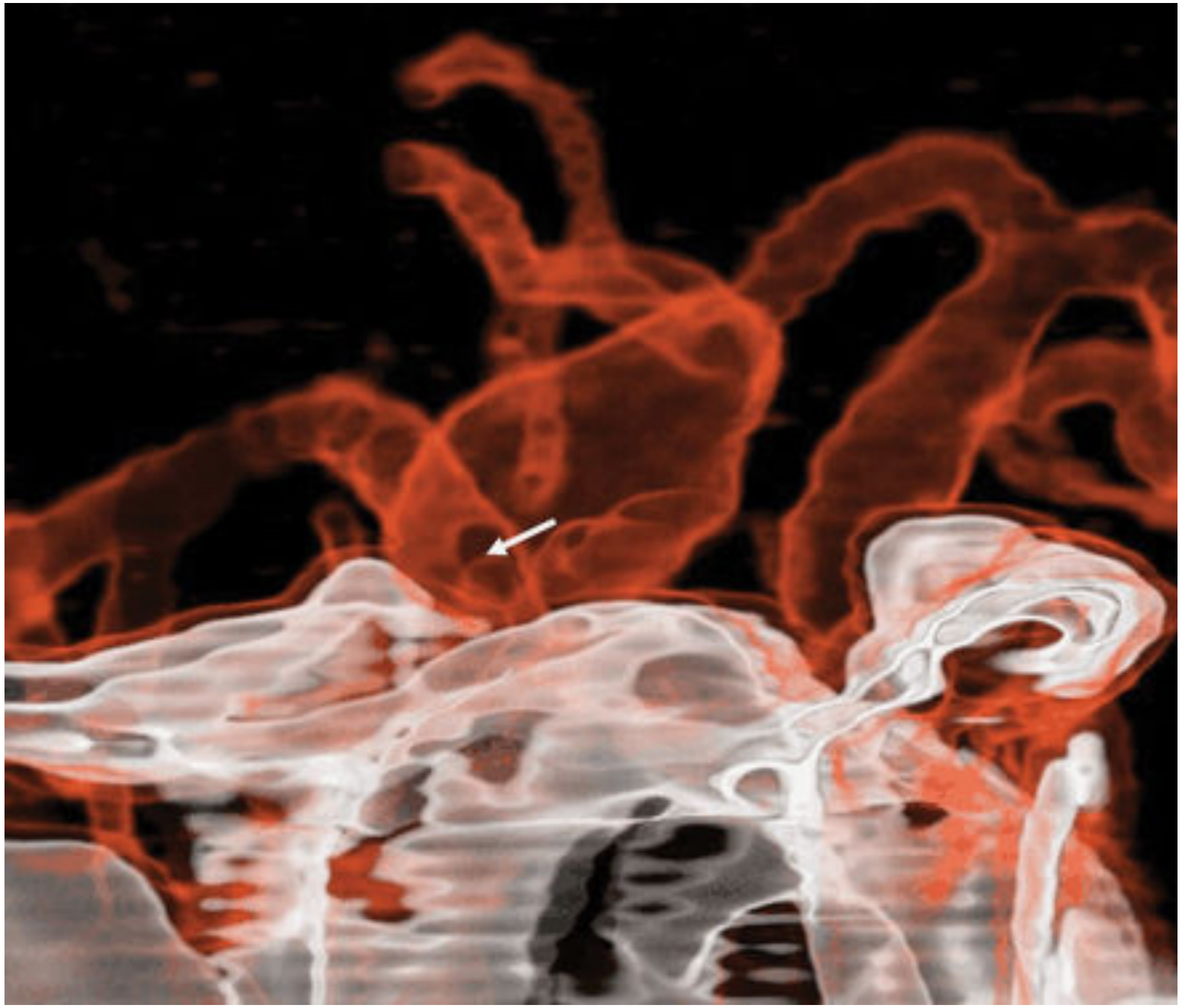
$$\mathbf{TF} : s \longrightarrow (C, \alpha)$$



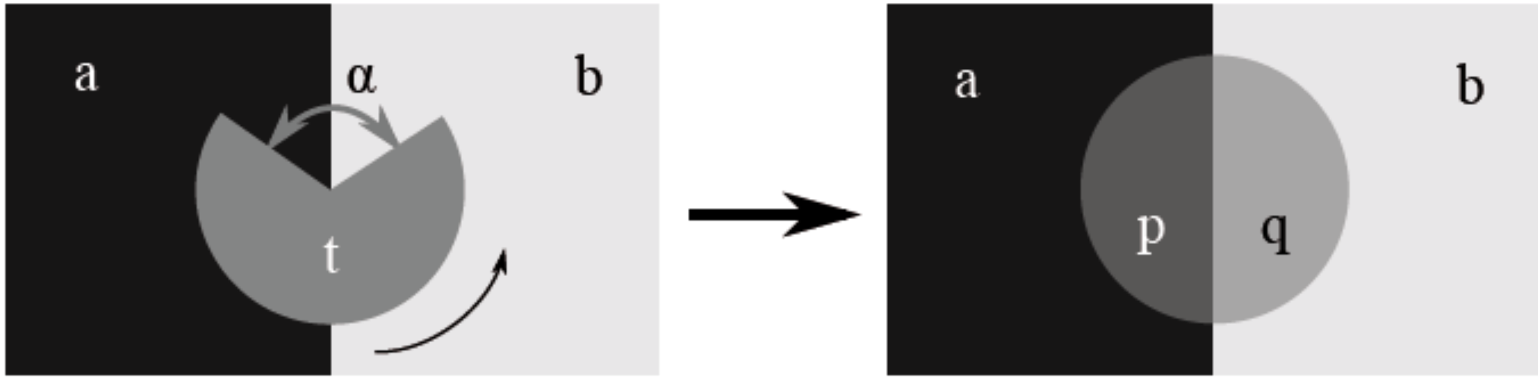
$$C(p) \approx \sum_{i=0}^{n} C_i \prod_{j=0}^{i-1} (1 - \alpha_j)$$

Direct Volume Rendering

radiographics.rsna.org



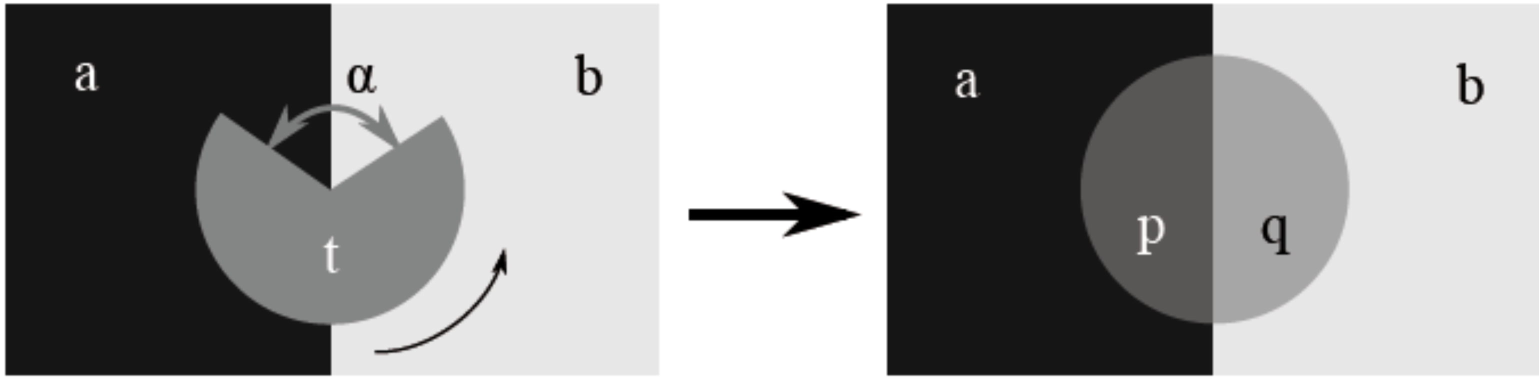
Transparency perception



p=?
q=?

[Metelli, 1974]

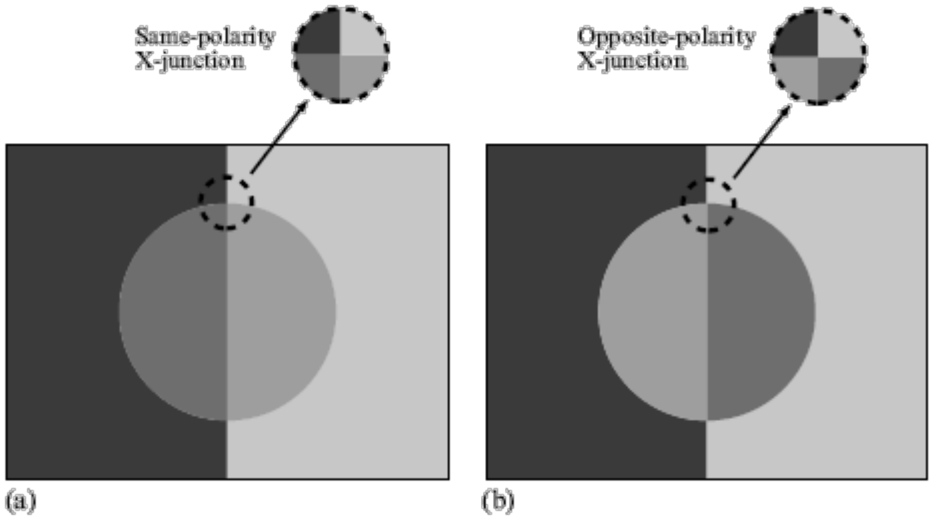
Transparency perception

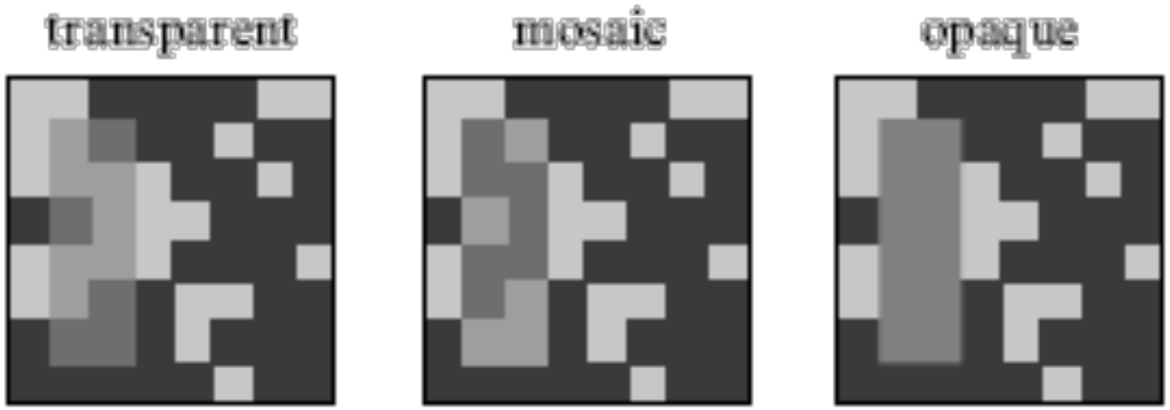


p=(1-α) t + α a
q=(1-α) t + α b

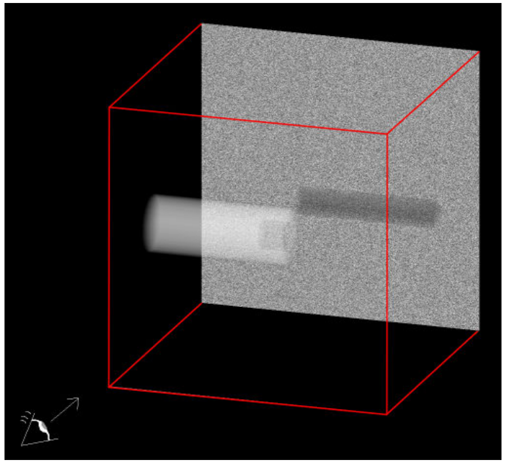
[Metelli, 1974]

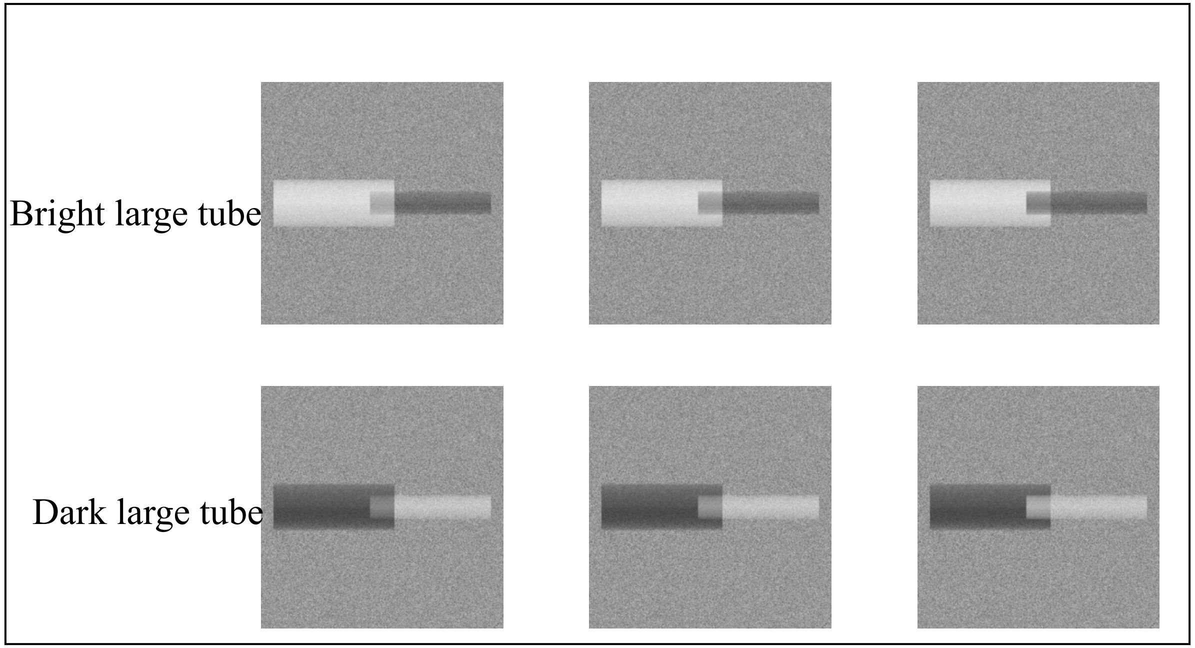
Transparency perception





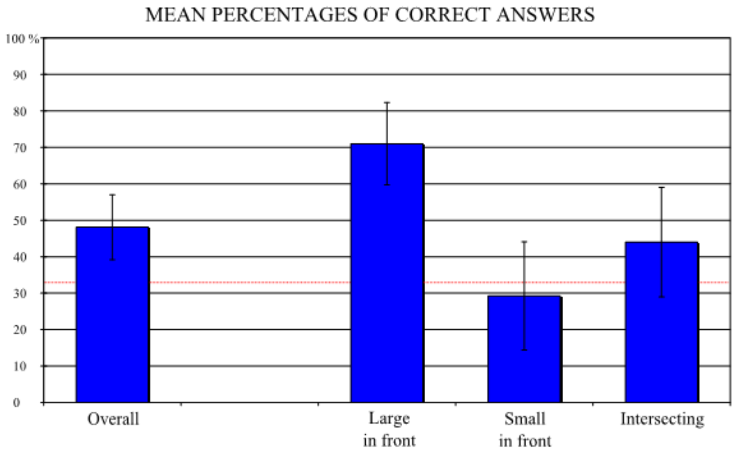
Evaluation of Depth Perception in DVR
Static experiment





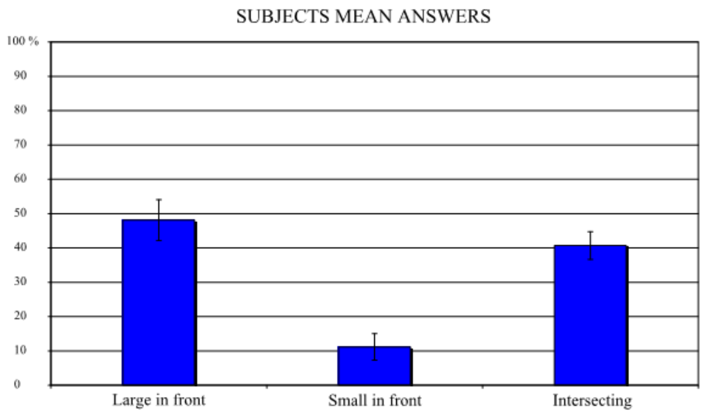
Boucheny, Bonneau & al, APGV 2007

Static experiment results

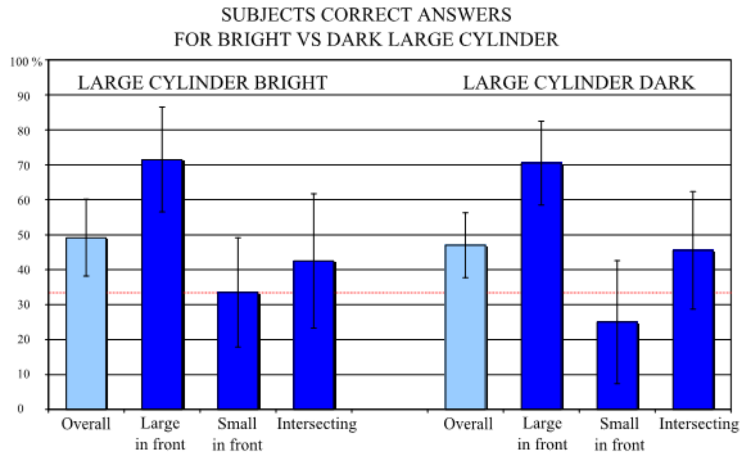


- Poor global performances

Boucheny, Bonneau & al, APGV 2007



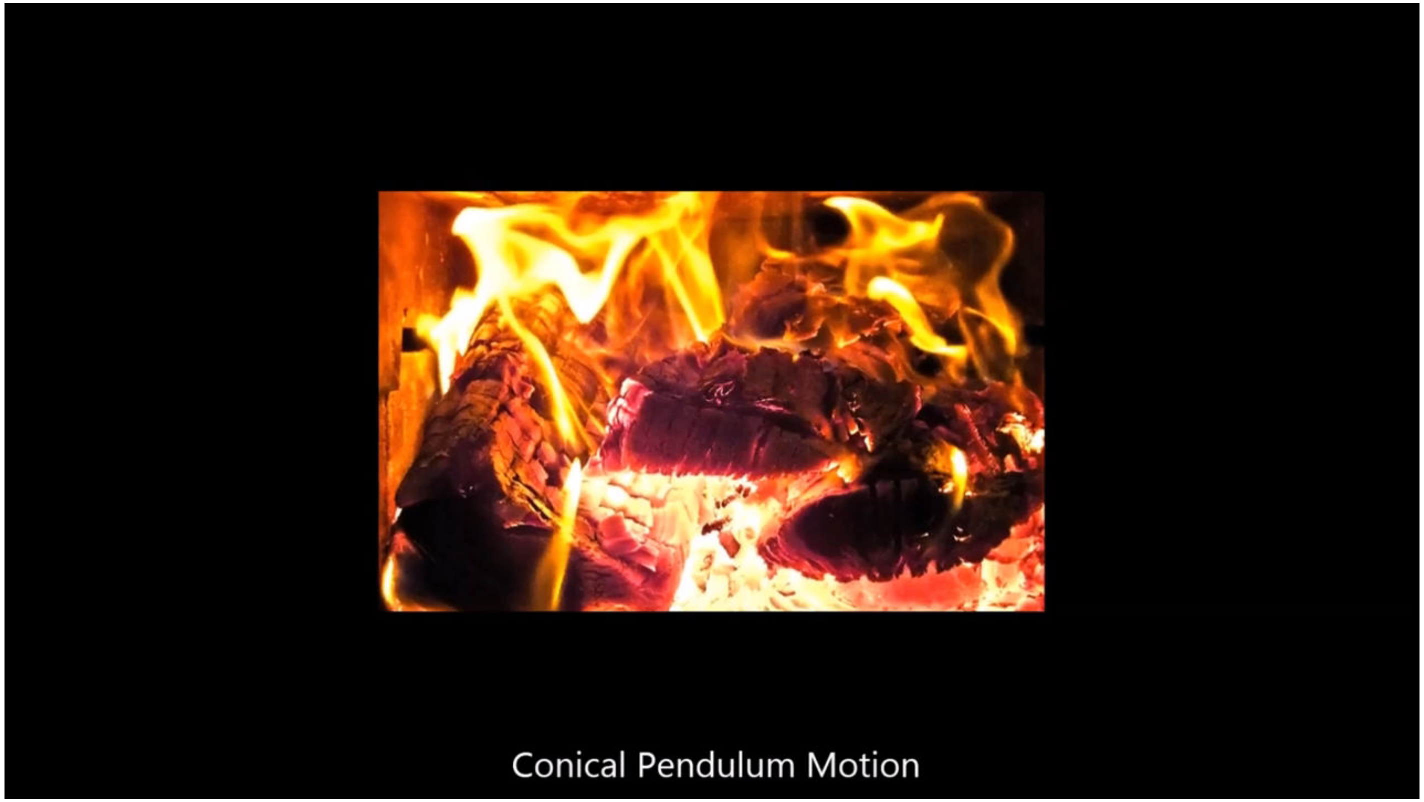
Bias for Large tube in front



Luminance does not impact

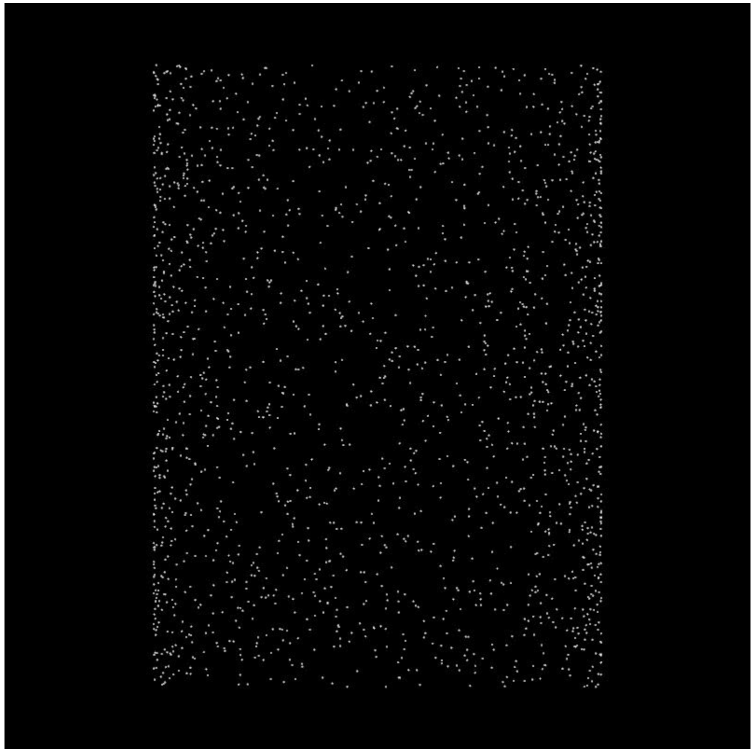
Dynamic experiment

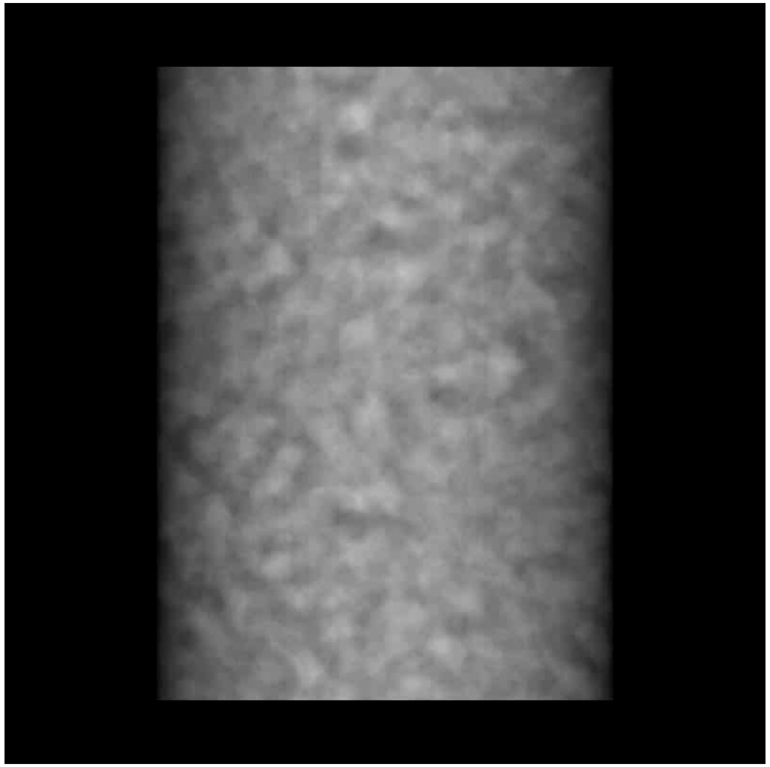
related to the Kinetic Depth Effect



[Bista&al 2016]

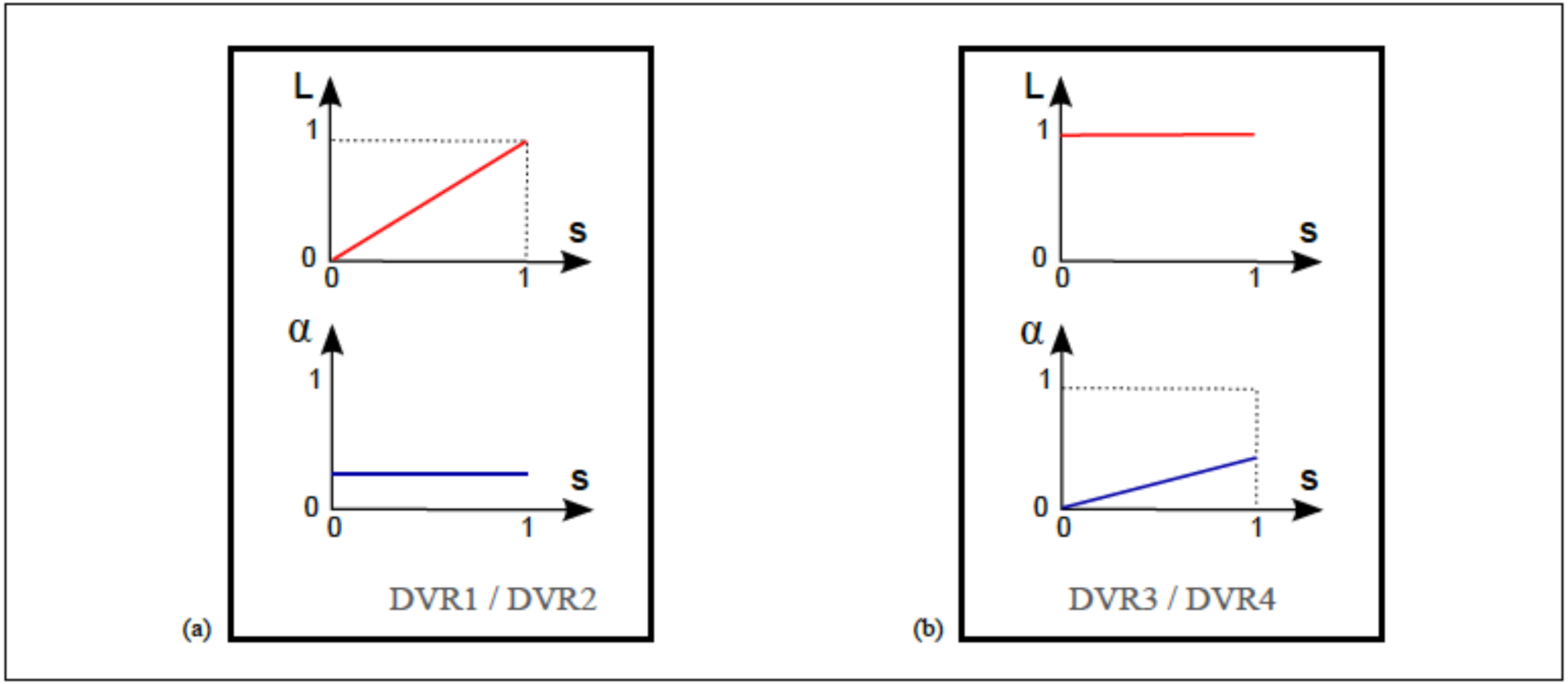
Dynamic experiment



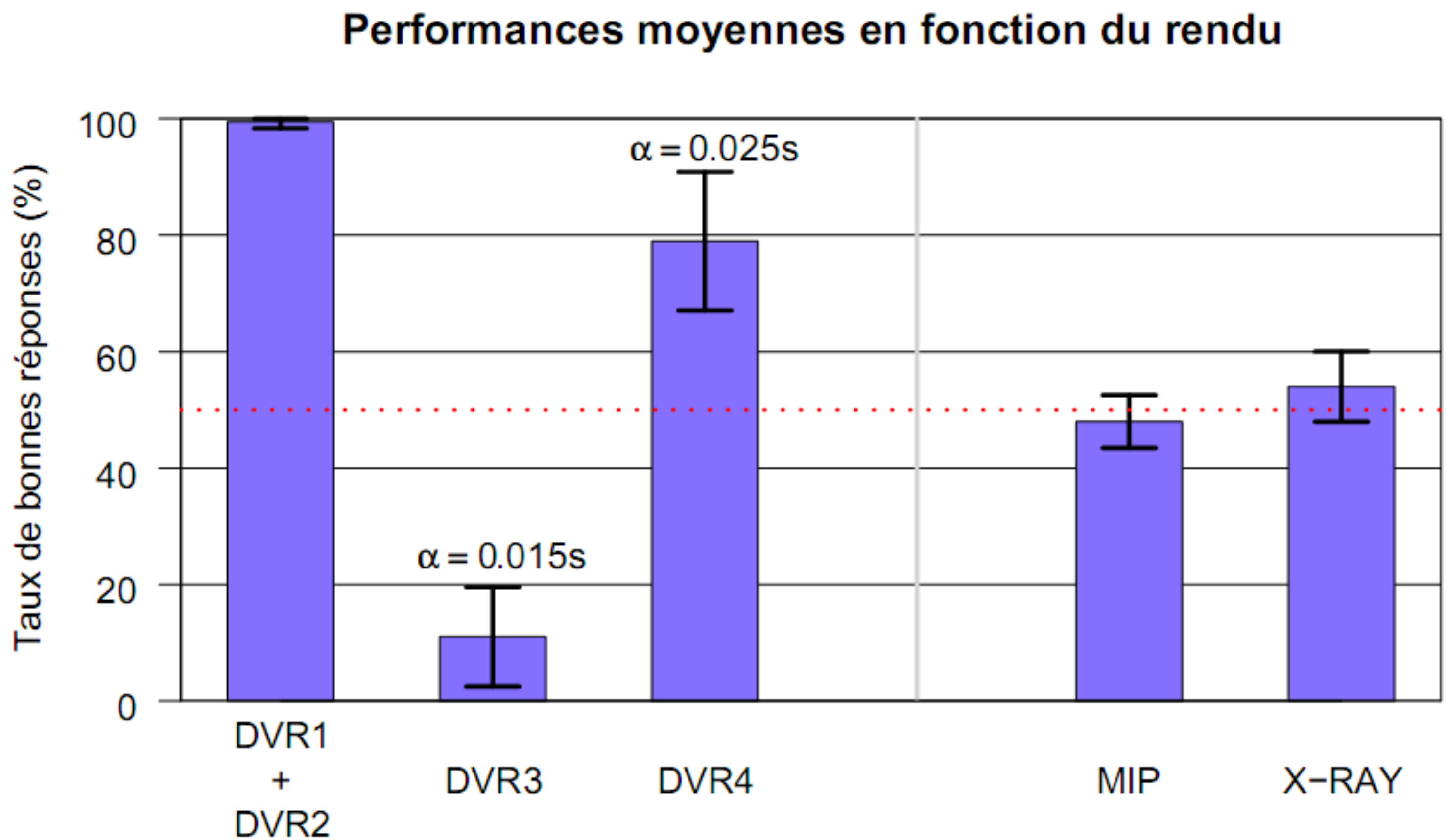


Boucheny, Bonneau & al ACM TAP 2009

Choice of transfer functions

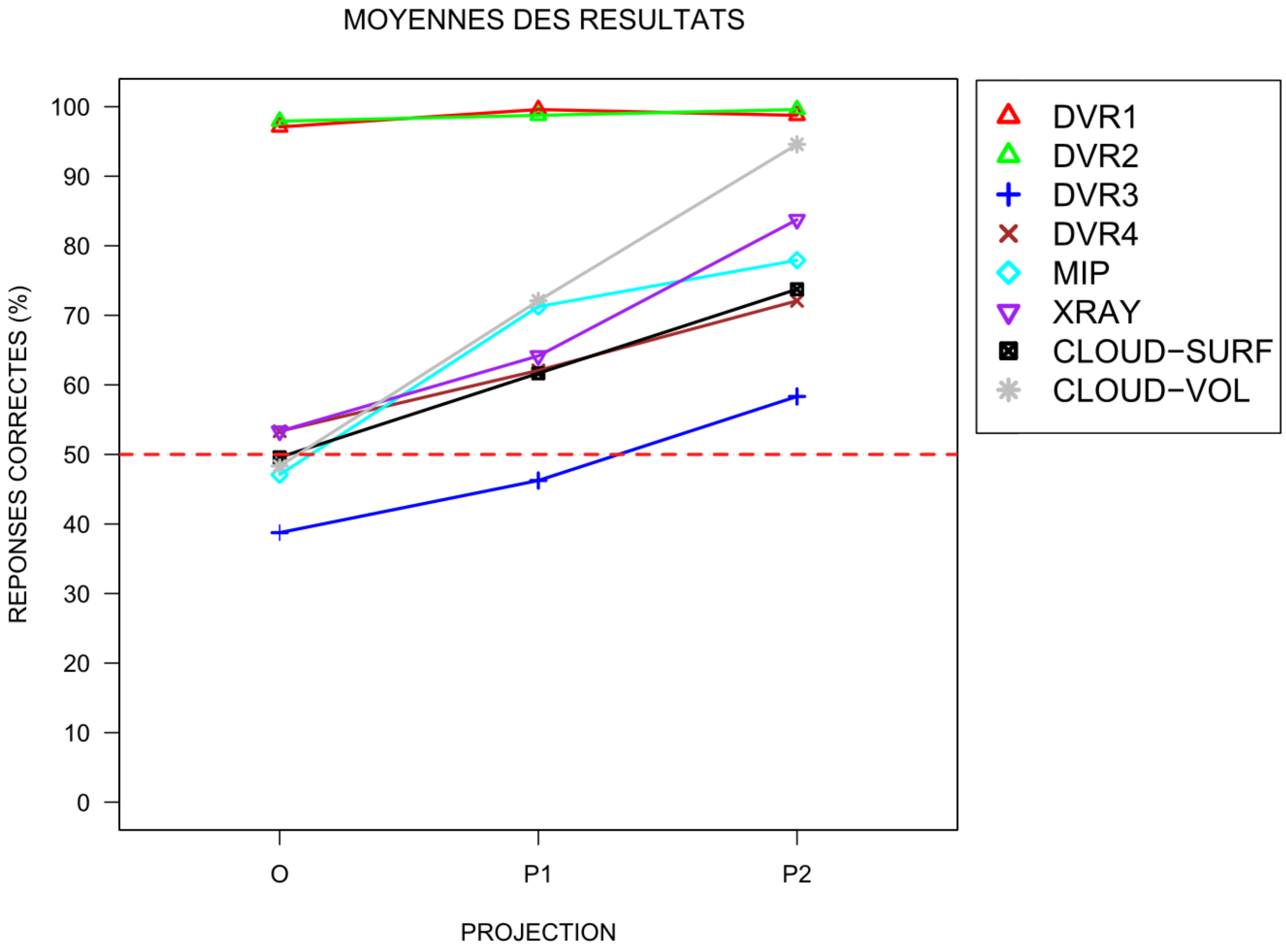


Dynamic experiment results



Boucheny, Bonneau & al ACM TAP 2009

Dynamic experiment results

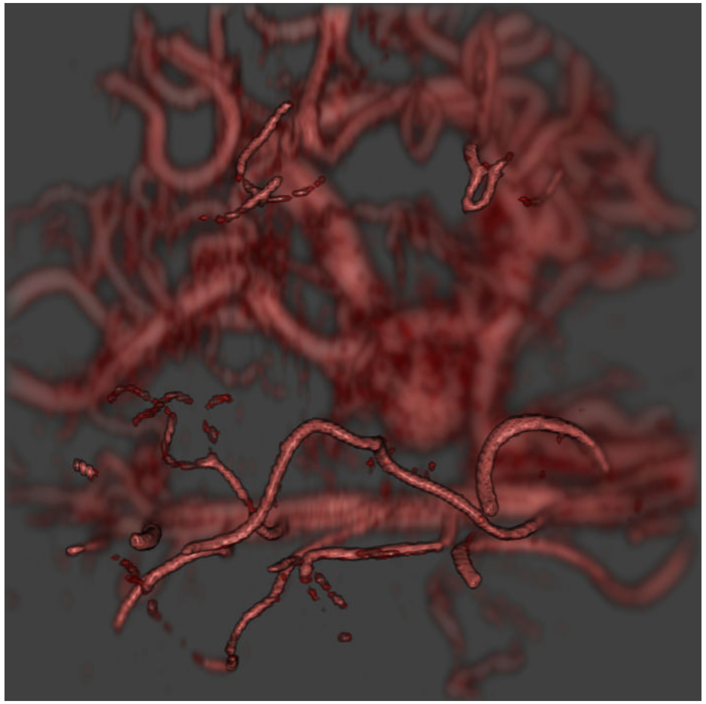


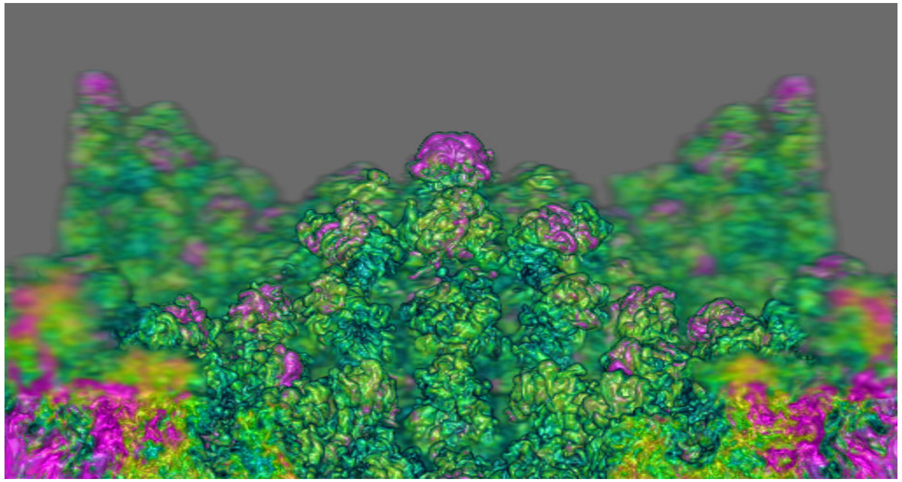
Boucheny, Bonneau & al ACM TAP 2009

Depth is difficult to perceive in DVR

Can we improve this?

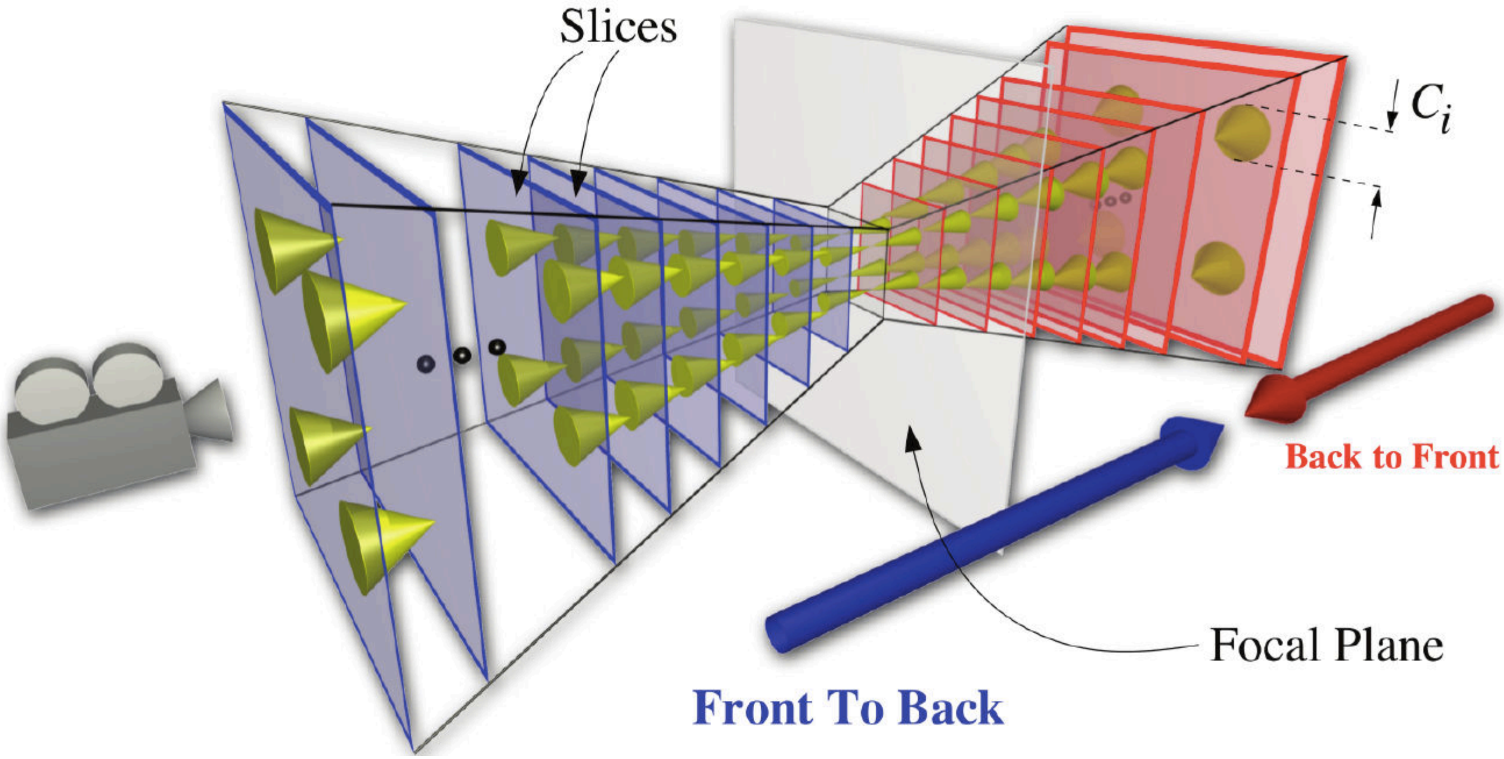
Depth Blur in Direct Volume Rendering





Grosset, Schott, Bonneau, Hansen, Pacific Visualization 2013

Depth Blur in Direct Volume Rendering

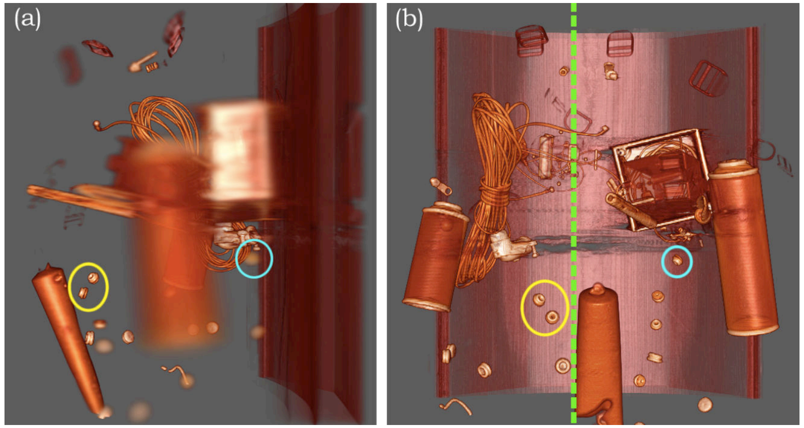


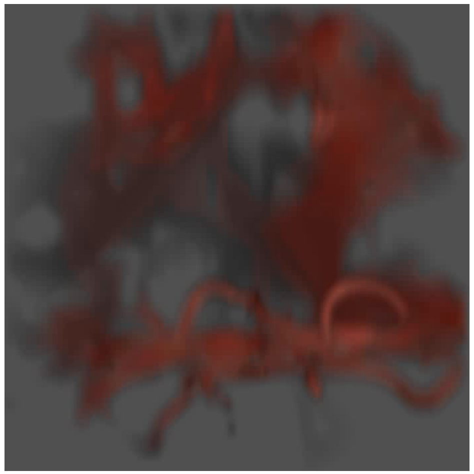
Schott, Grosset, martin, Pegoraro, Smith, Hansen, CGF 2009

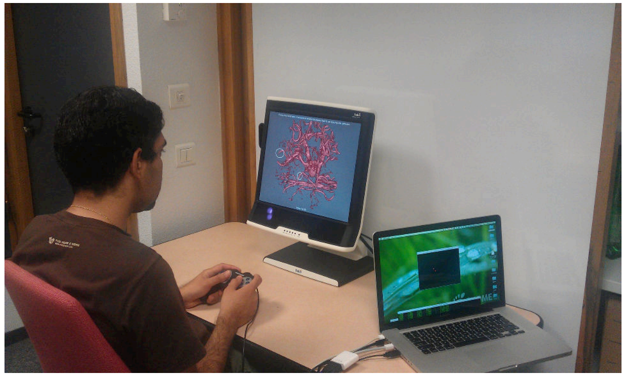
Hypotheses

- **HYP 1**: DoF will improve the accuracy of ordinal depth perception in a volume rendered image where there are multiple features.
- **HYP 2**: DoF will improve the speed of ordinal depth perception in a volume rendered image where there are multiple features.
- **HYP 3**: If users view a moving focal plane, correct perception of ordinal depth will improve.

Depth Blur Experiment in DVR



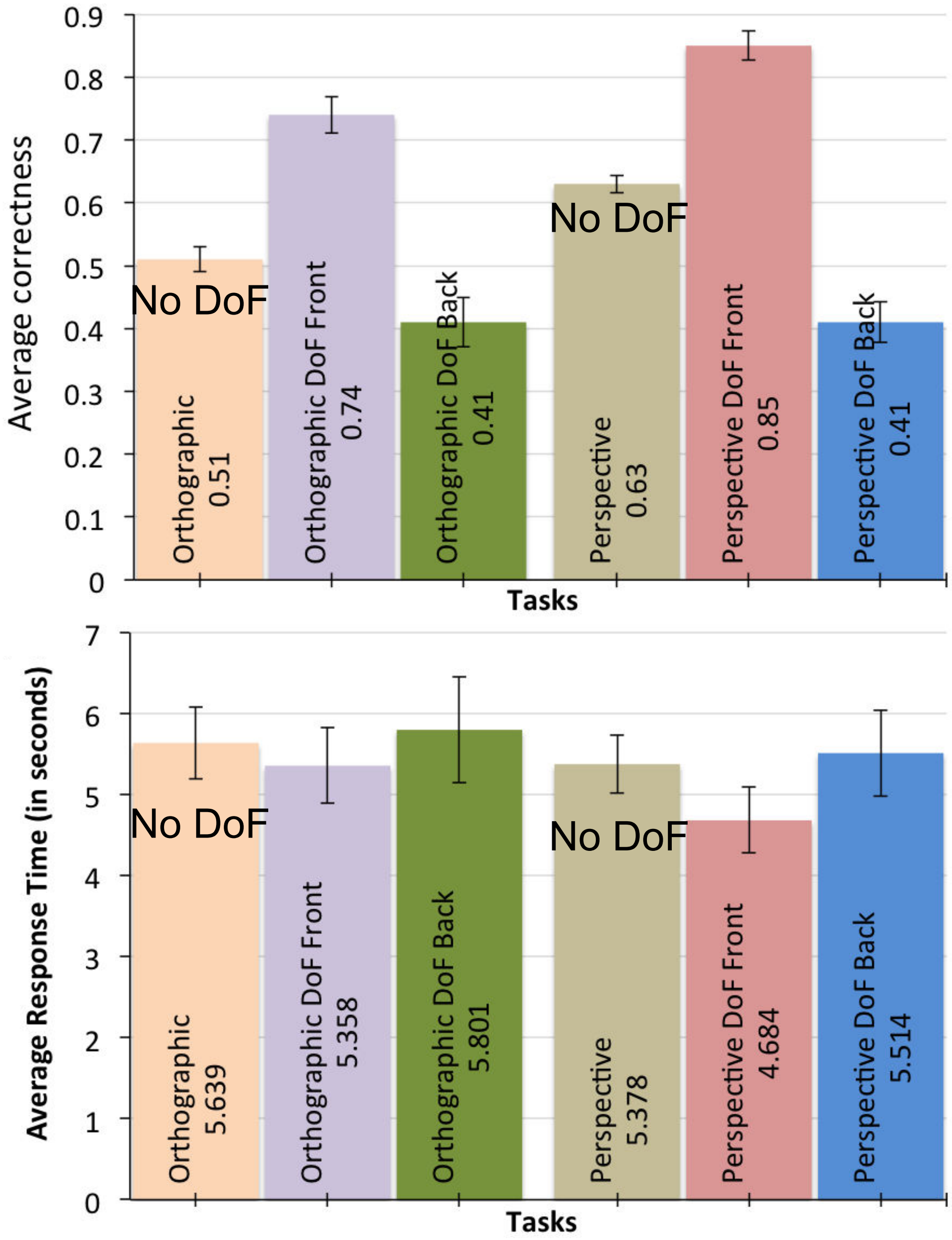




Grosset, Schott, Bonneau, Hansen, Pacific Visualization 2013

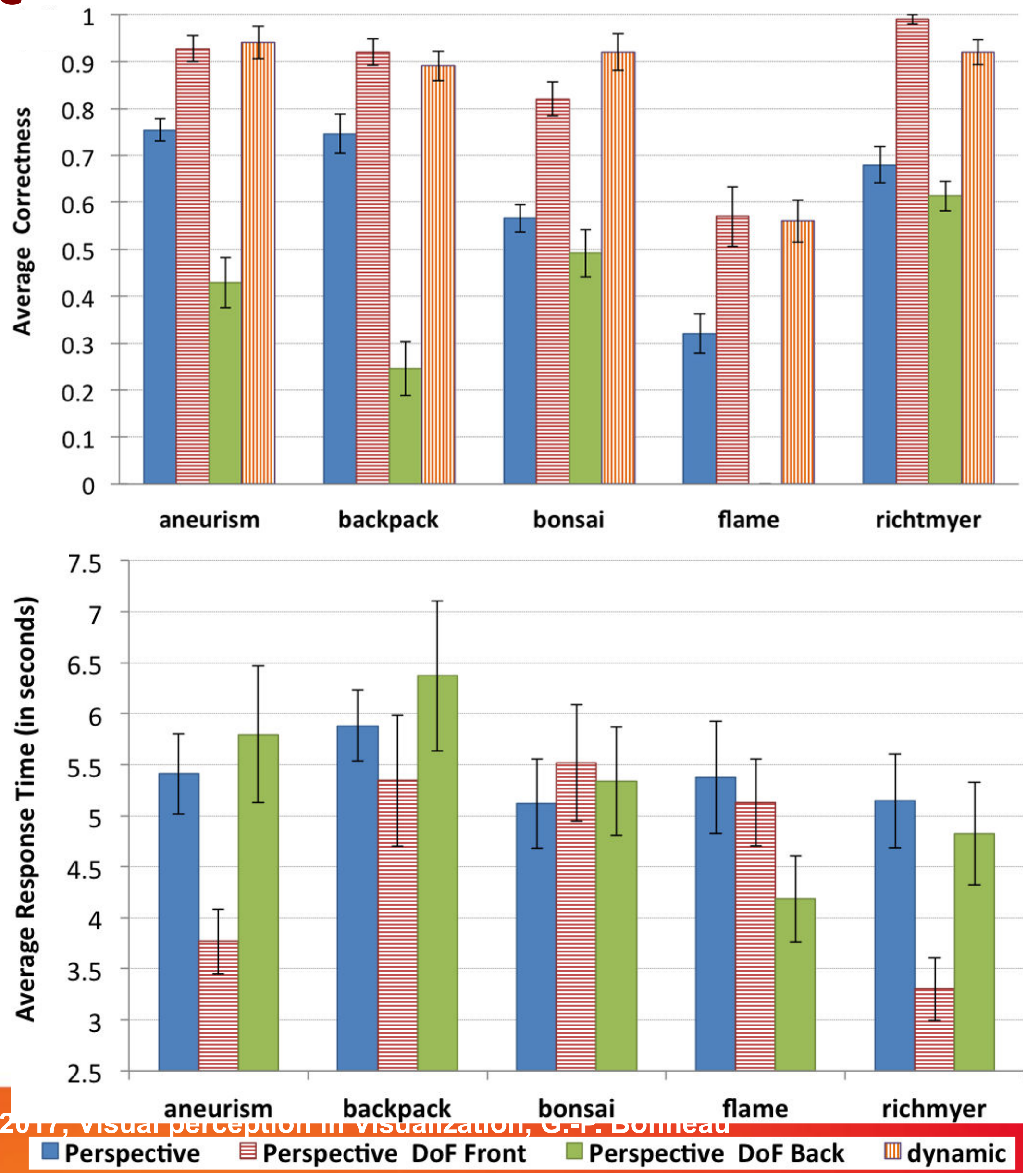
Results: Overall

- HYP1 & HYP2
- Depth of Field is NOT always beneficial
  - DoF on Front feature helps
  - DoF on Back feature has reverse effects
  - Why?
    - Depth Cue conflict?



Results: Dataset

- DoF on Front feature is helpful
- Not equally beneficial
  - Translucent datasets are hard to understand

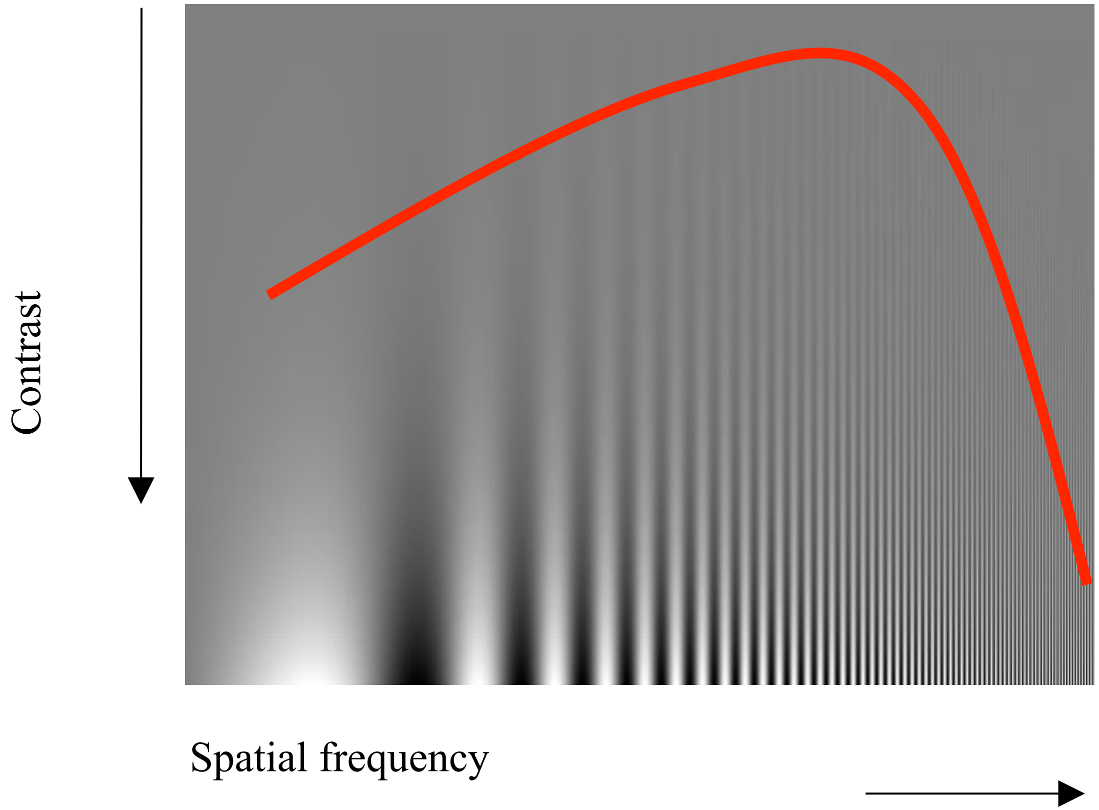


Contrast sensitivity perception

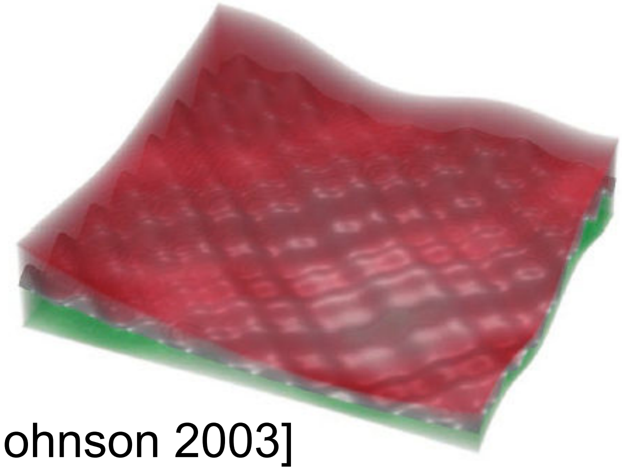
3

Visualization of Data with Uncertainty

Contrast sensitivity function

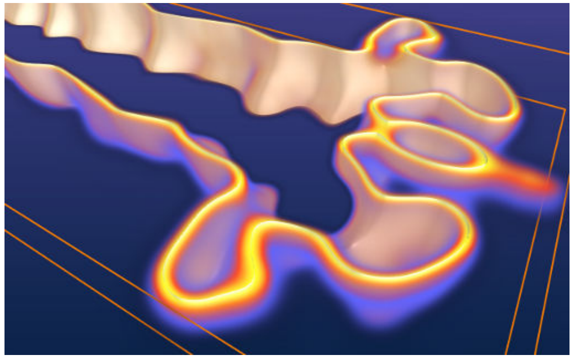


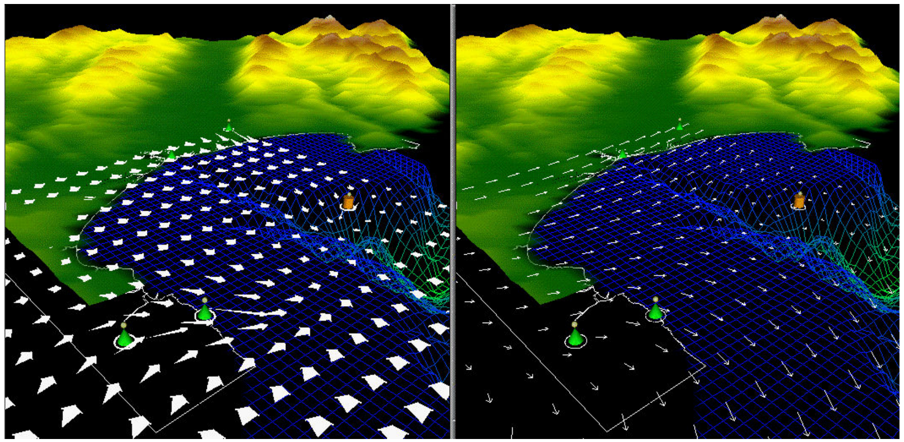
Visualization of Data with Uncertainty



[Johnson 2003]

ZIB 2011

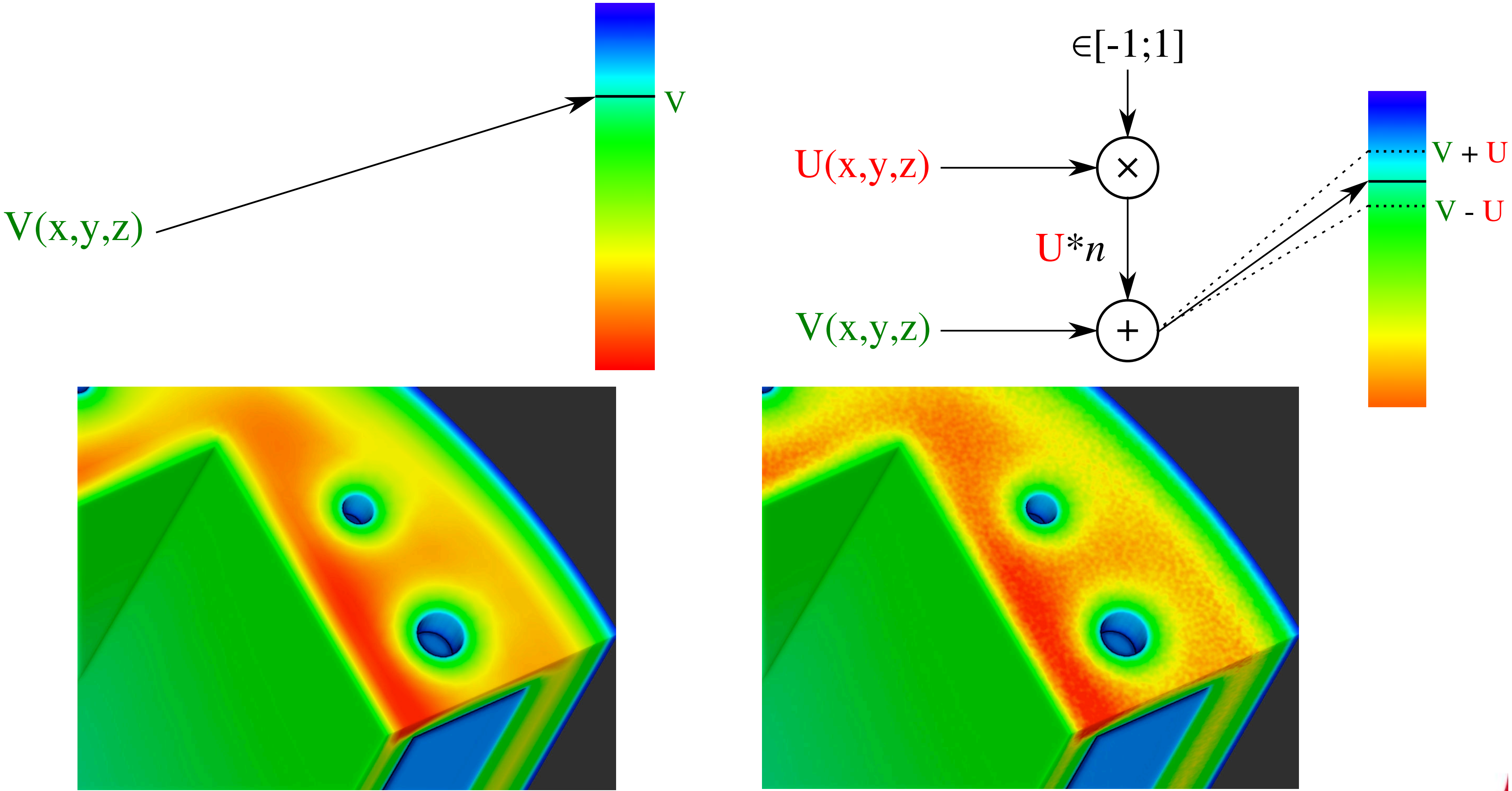




Wittenbrink & al. 1995

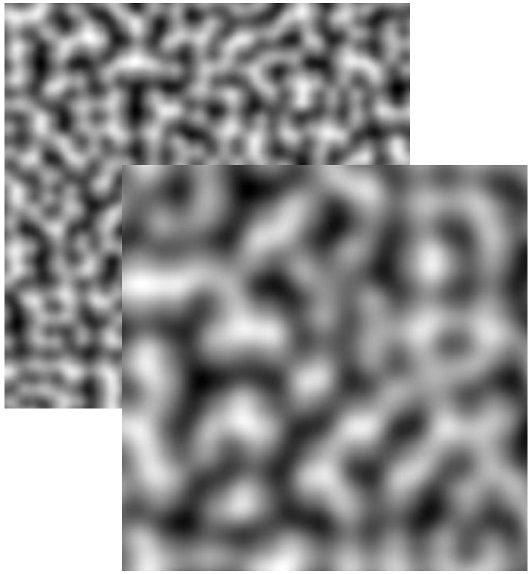
Uncertainty Visualization using Noise

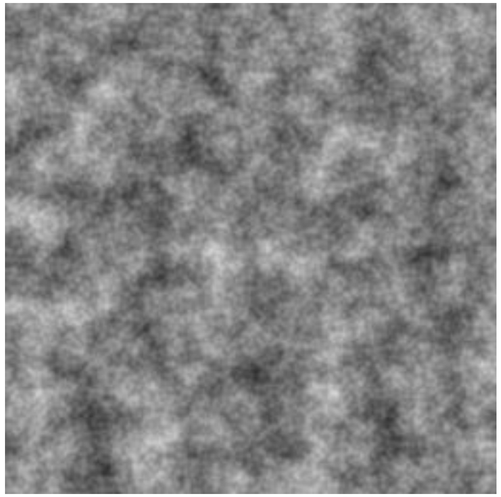
Coninx, Bonneau & al., APGV 2011

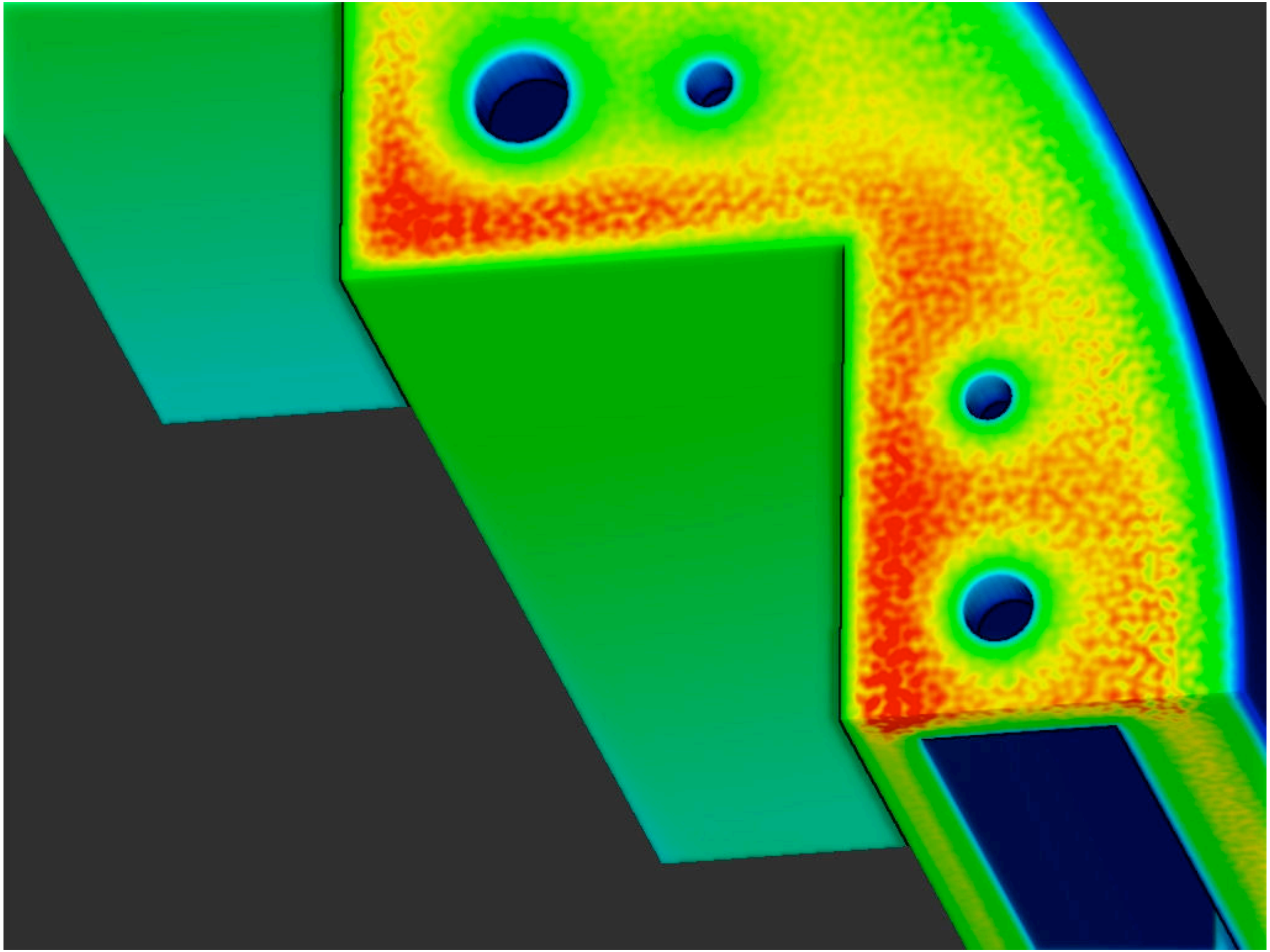


Perlin Noise

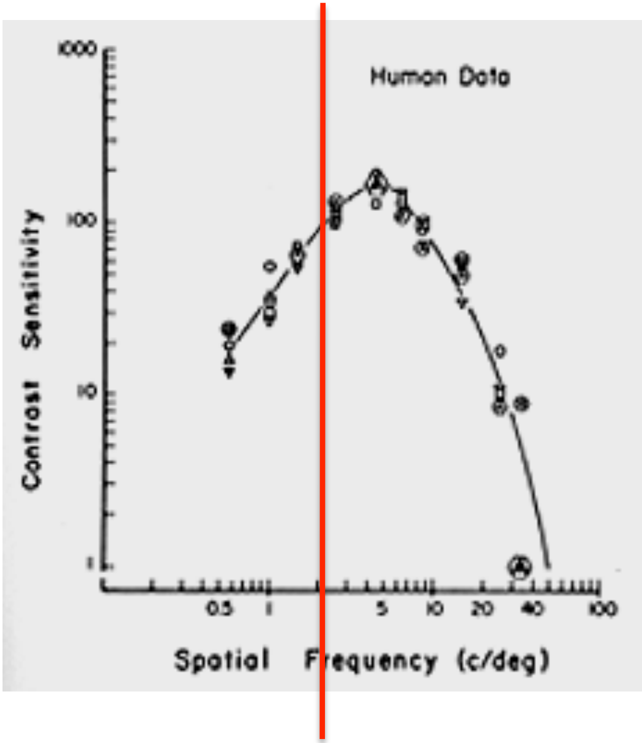
$$n_{f_0,p}(\vec{x},t) = \sum_i p^i N(f_0 2^i \vec{x}, t)$$



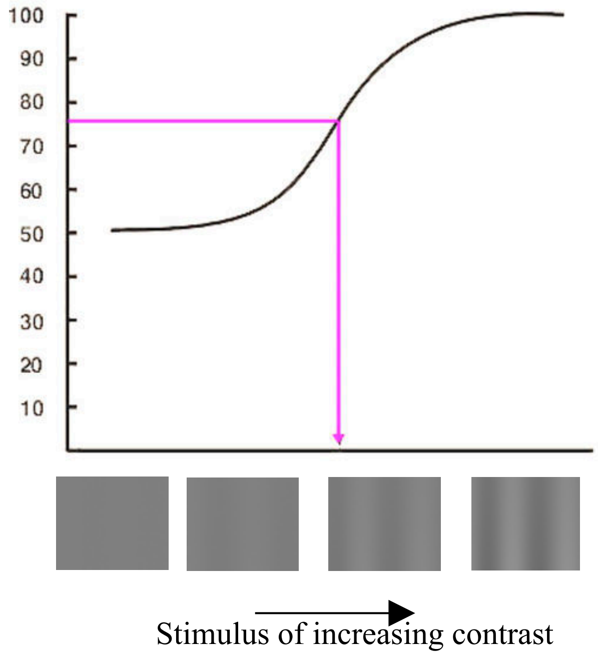




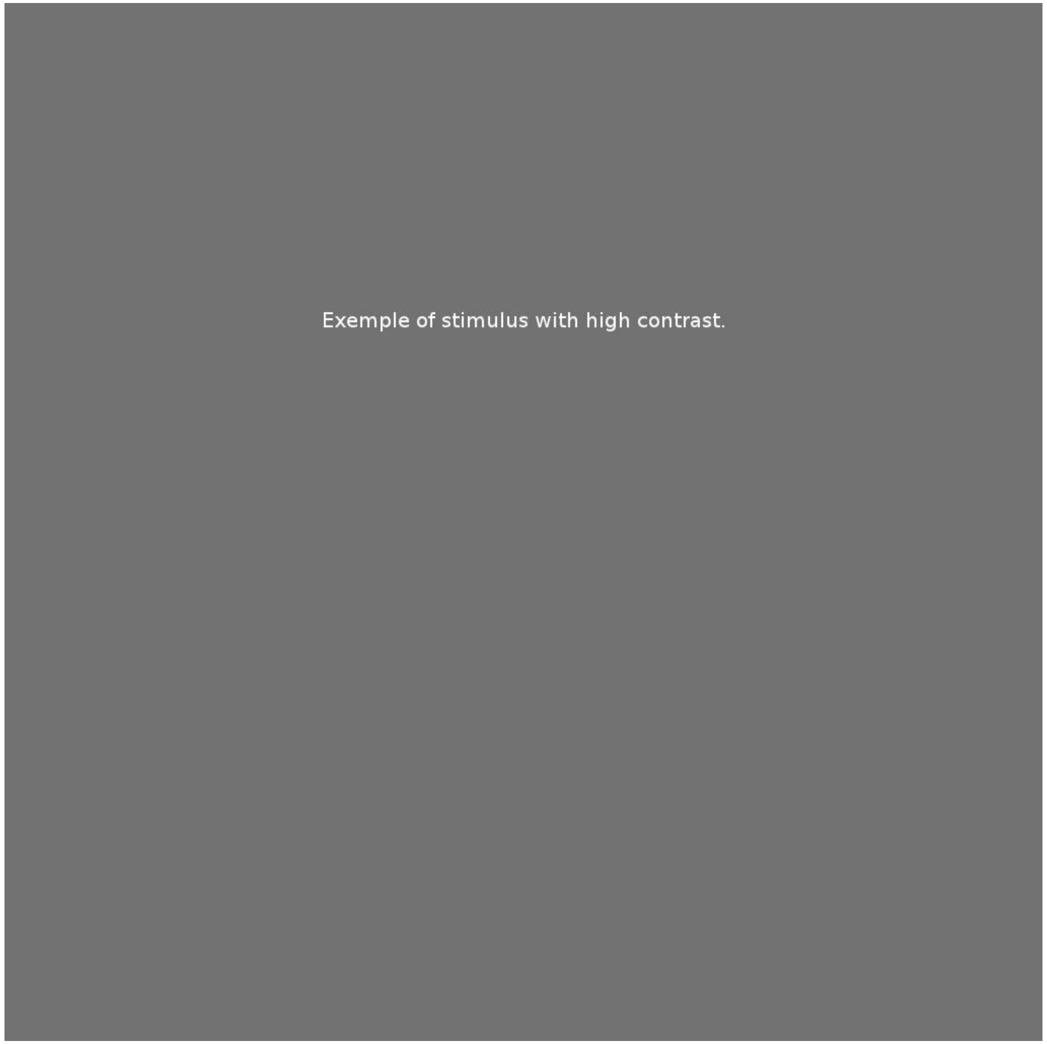
Coninx, Bonneau & al., APGV 2011



DeVaIois & DeValois (1988)
Spatial Vision. Oxford: Oxford University Press



Stimulus of high contrast



Stimulus near threshold contrast

Psychophysik experiment

- Choice of 4 values of frequency f0 and persistence p

  => 16 stimuli
- f0 = { 2, 4, 8, 16}   p = { 0., 0.25, 0.5, 0.75}
- Stimulus of size 256x256
- LCD with pixel size 0.295mm, screen-subject distance 2m

  => 120 pixels per degree
- 30 questions to measure a threshold => 30 * 16 = 480 quest., ~5s for each quest. => ~40mn duration for each subject

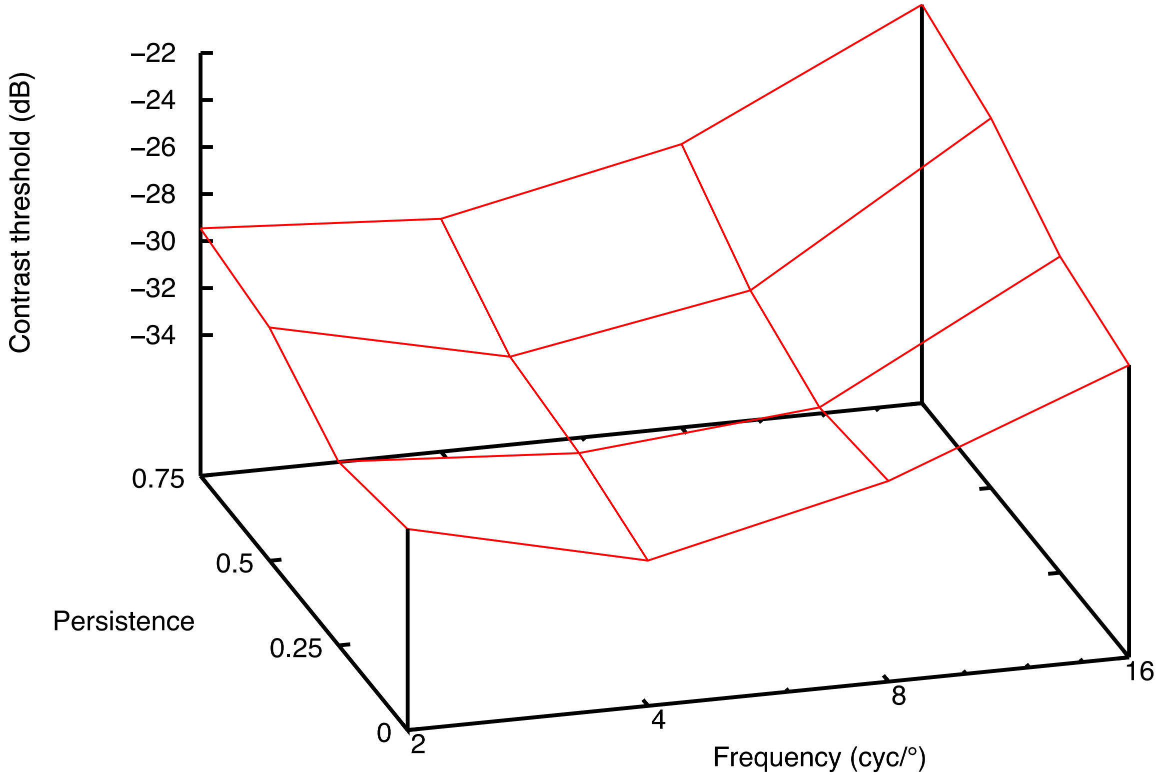
Psychophysik experiment pitfalls

- Eliminate all biases in the stimuli
- Calibrate screen precisely
- resolution in gray value must be < 0.25% of measured threshold

…

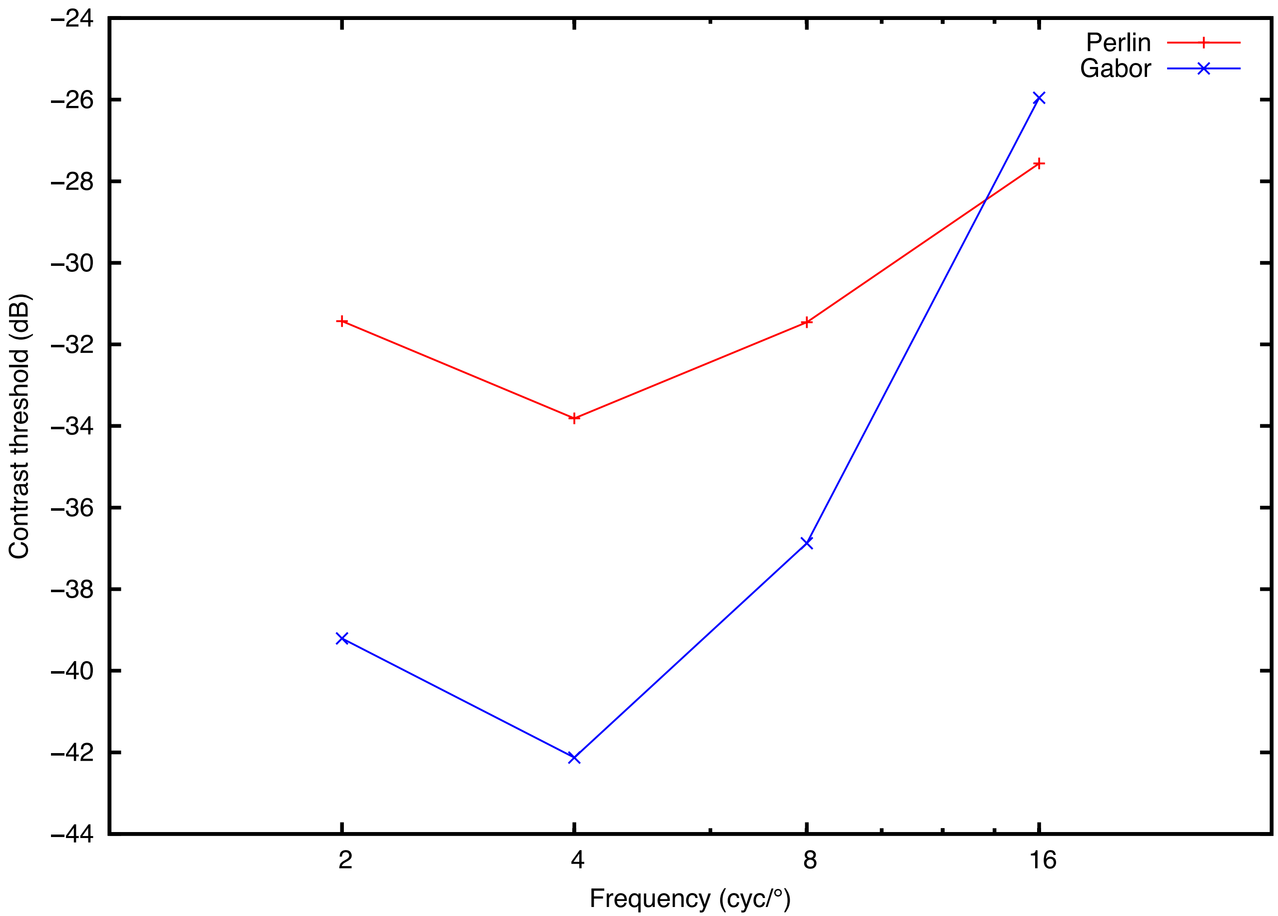
=> necessary to collaborate with perception experts!

Sensitivity Thresholds for Perlin Noise

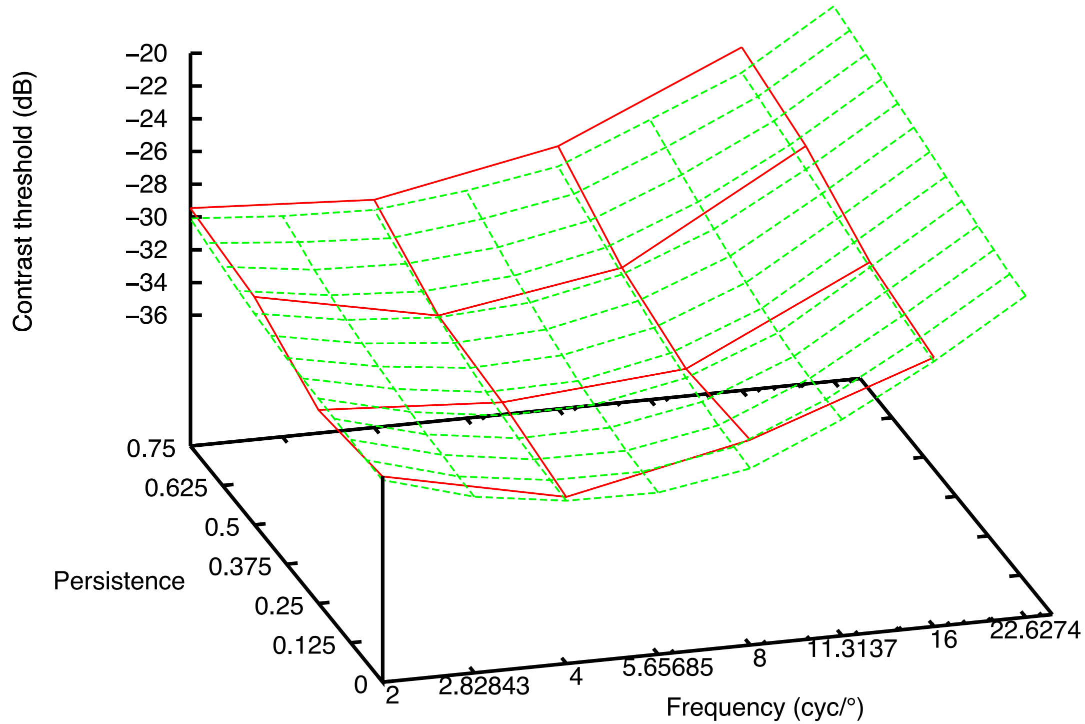


Coninx, Bonneau & al., APGV 2011

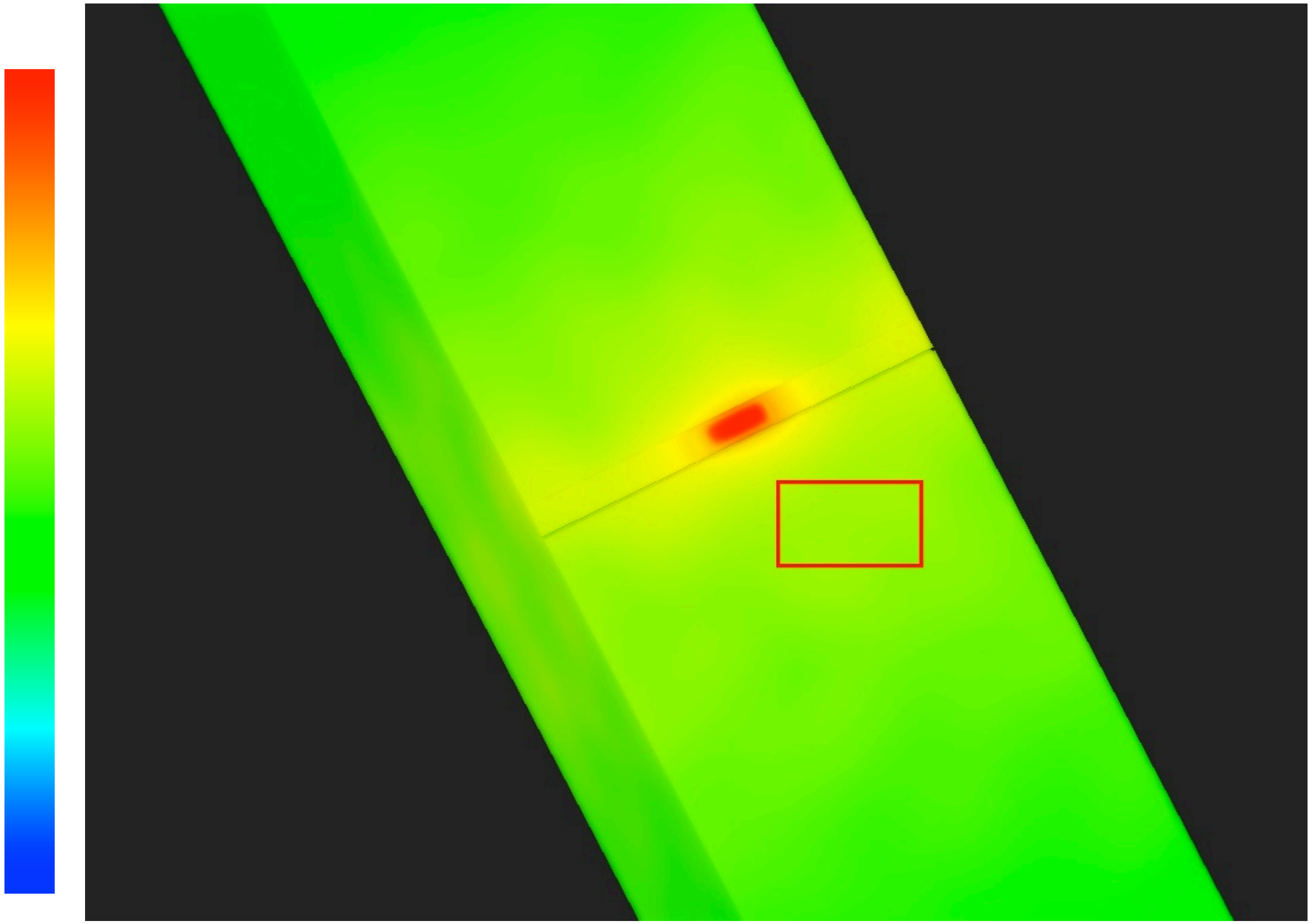
Threshold for Regular vs. Stochastic Stimuli

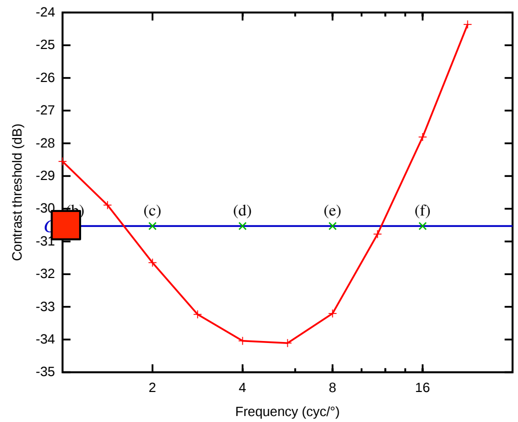


Model for Automatic Threshold Computation



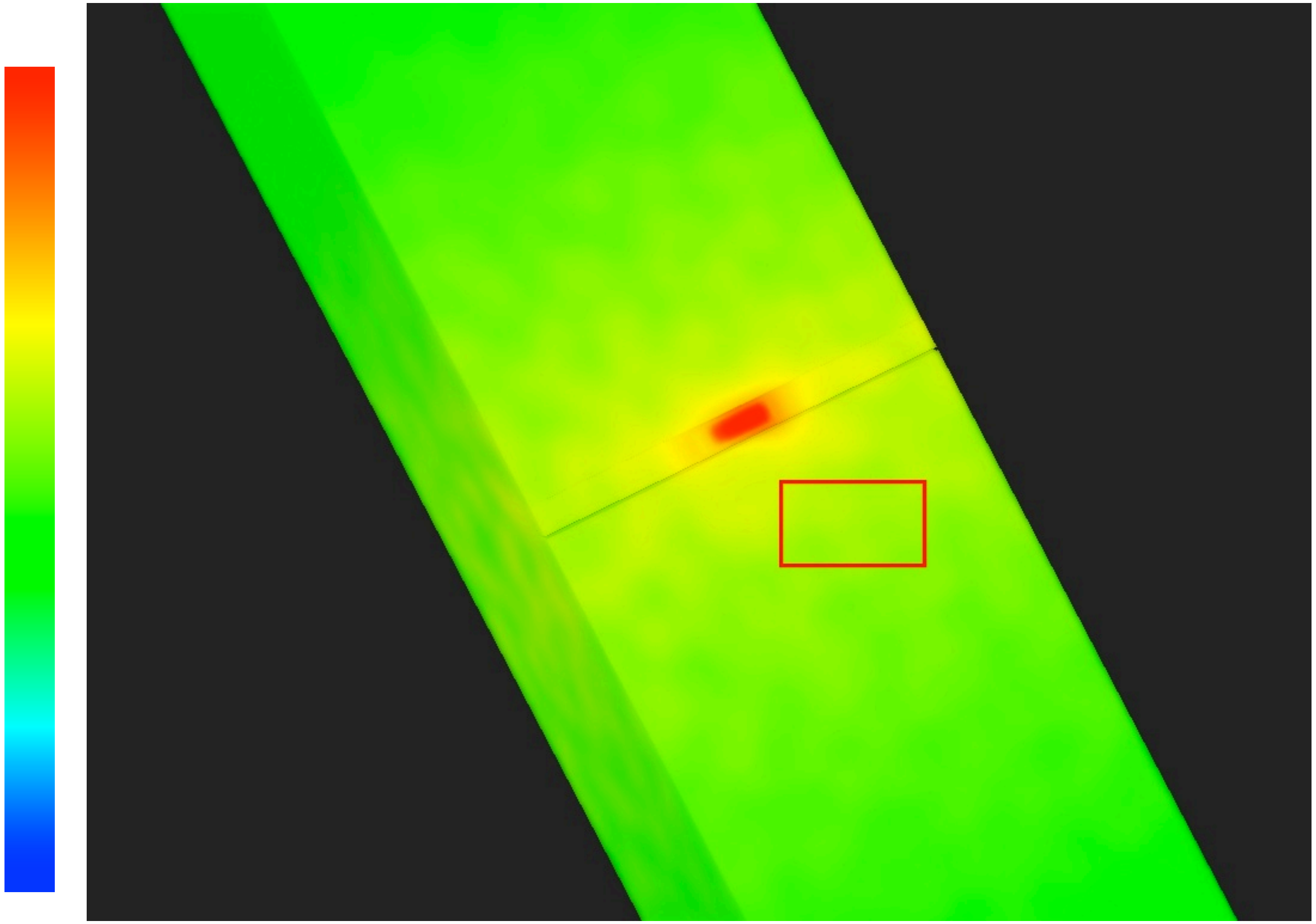
Using Sensitivity Thresholds

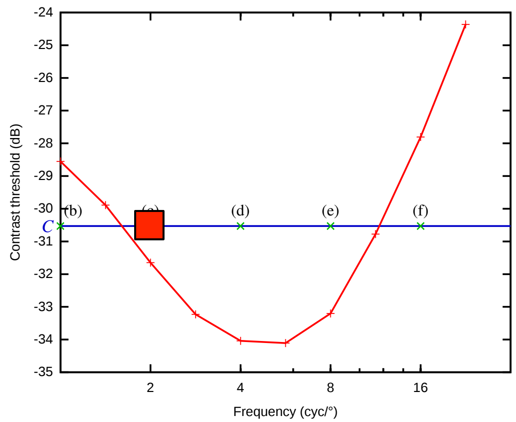




Coninx, Bonneau & al., APGV 2011

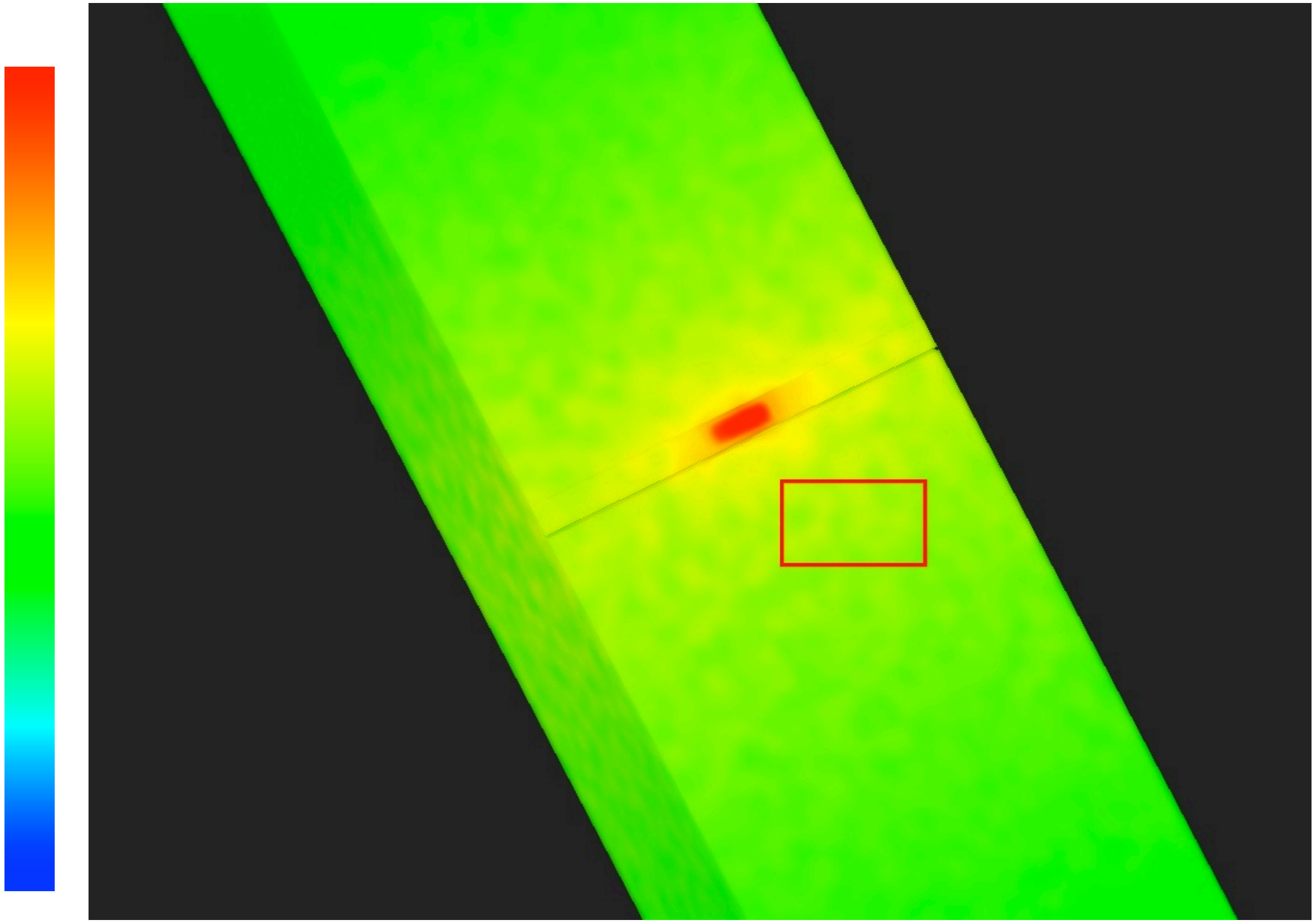
Using Sensitivity Thresholds

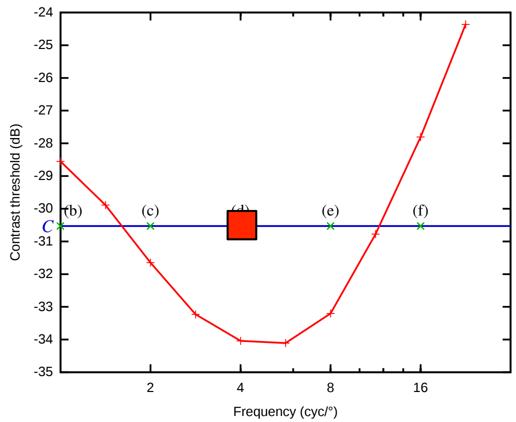




Coninx, Bonneau & al., APGV 2011

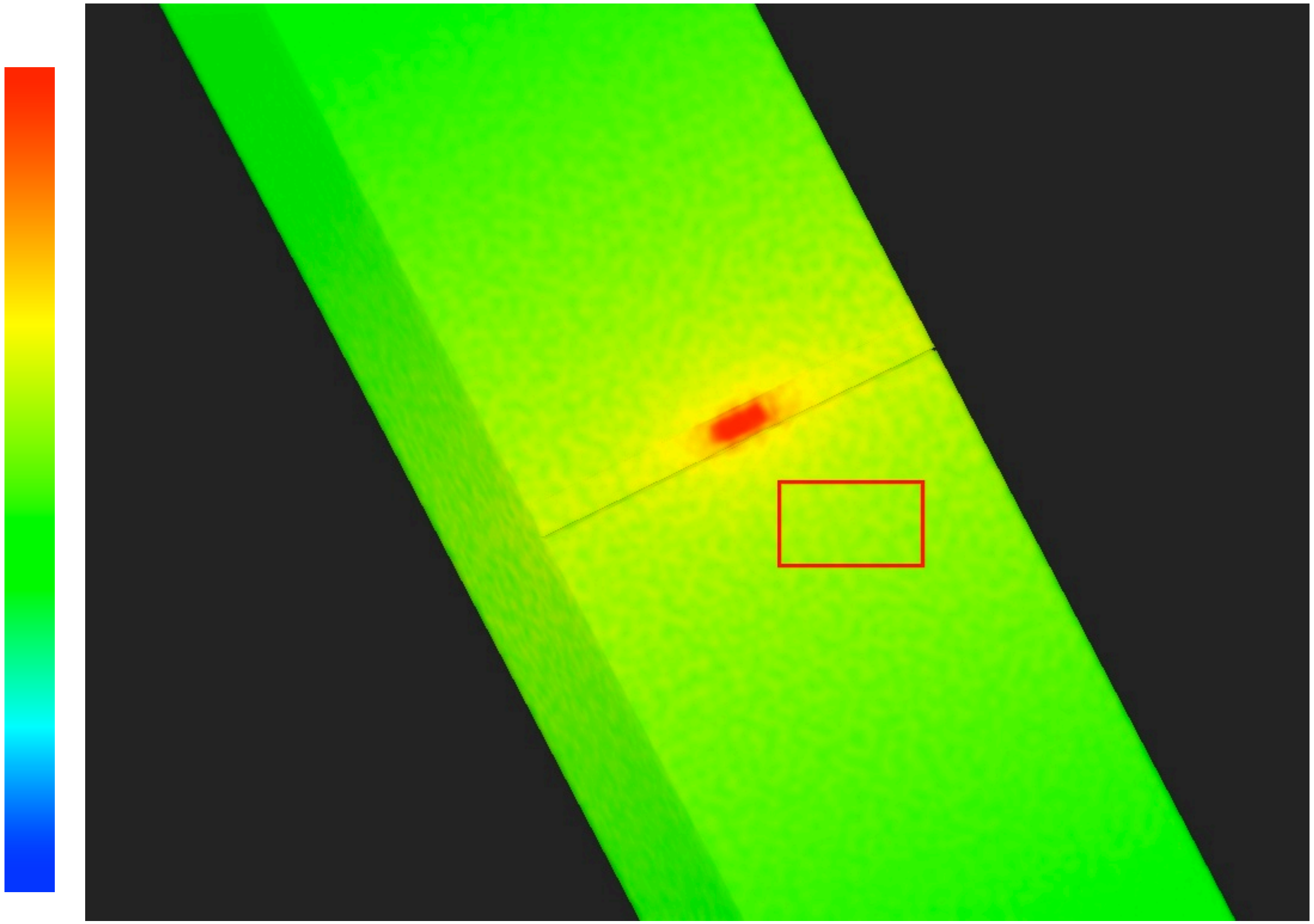
Using Sensitivity Thresholds

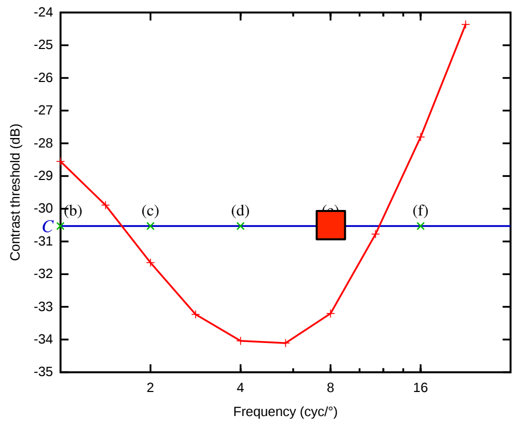




Coninx, Bonneau & al., APGV 2011

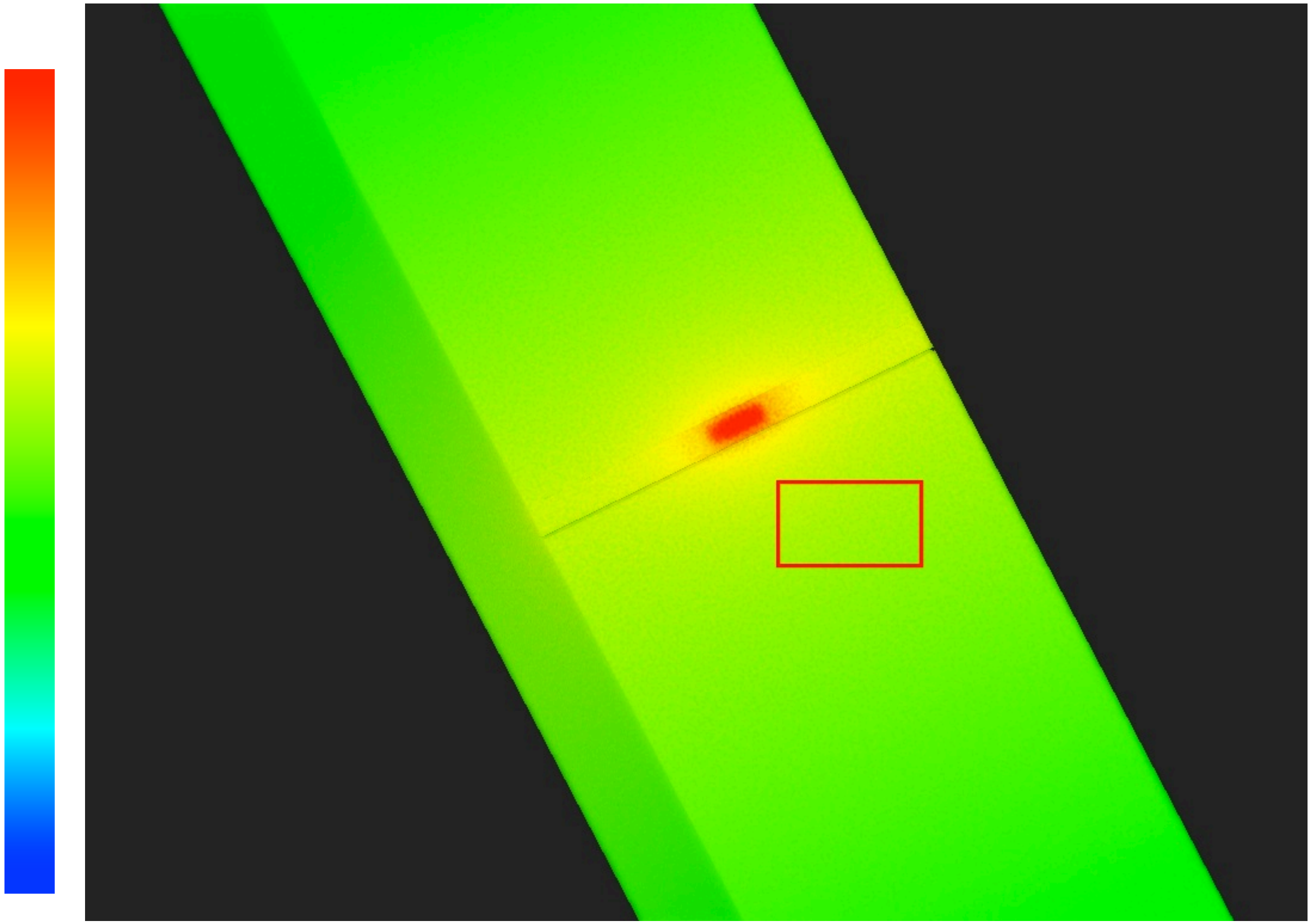
Using Sensitivity Thresholds

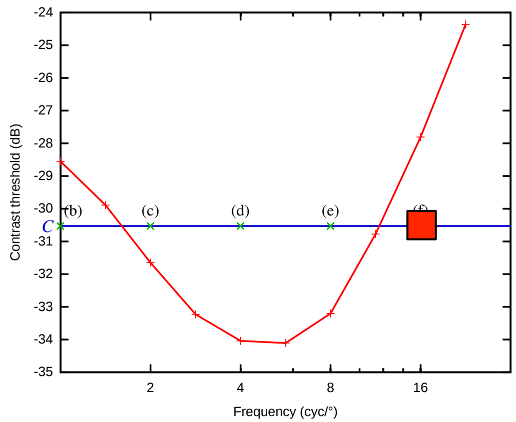




Coninx, Bonneau & al., APGV 2011

Using Sensitivity Thresholds





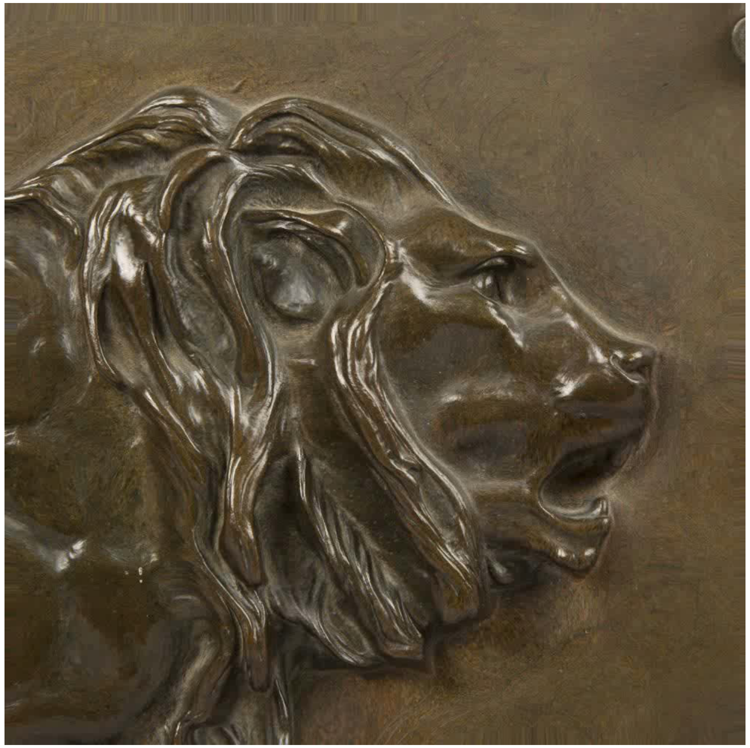
Coninx, Bonneau & al., APGV 2011

Perception of shape

4

Image based shape manipulation

Modifying Perceived Shape by Warping



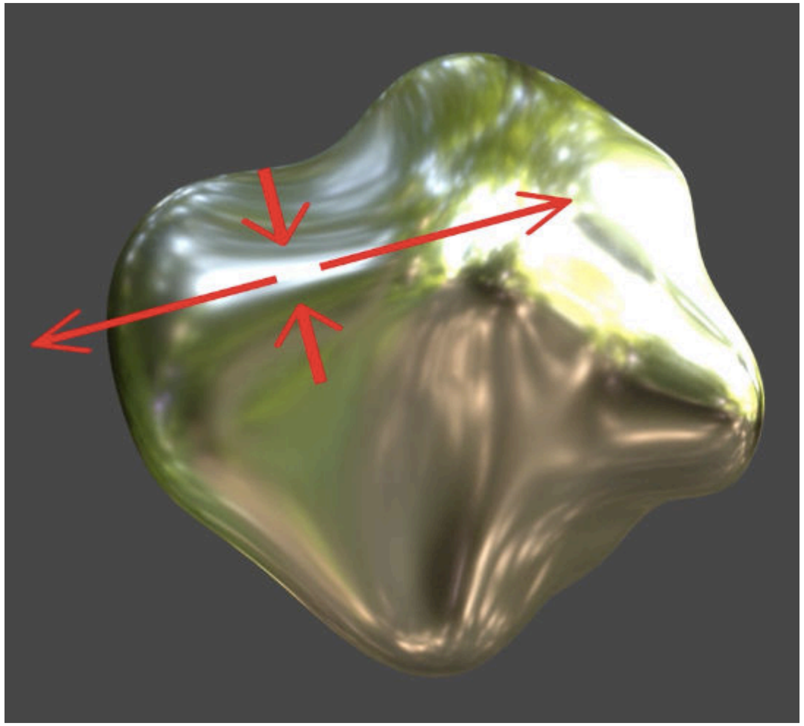
R. Vergne, P. Barla, G.-P. Bonneau, R.W. Fleming
Flow-Guided Warping for Image-Based Shape Manipulation
Siggraph 2016

Related Works

- Image manipulation
- [Boyadzhiev et al.2015] [Wu et al. 2012] [Wadhwa et al. 2013] [Wadhwa et al. 2015]

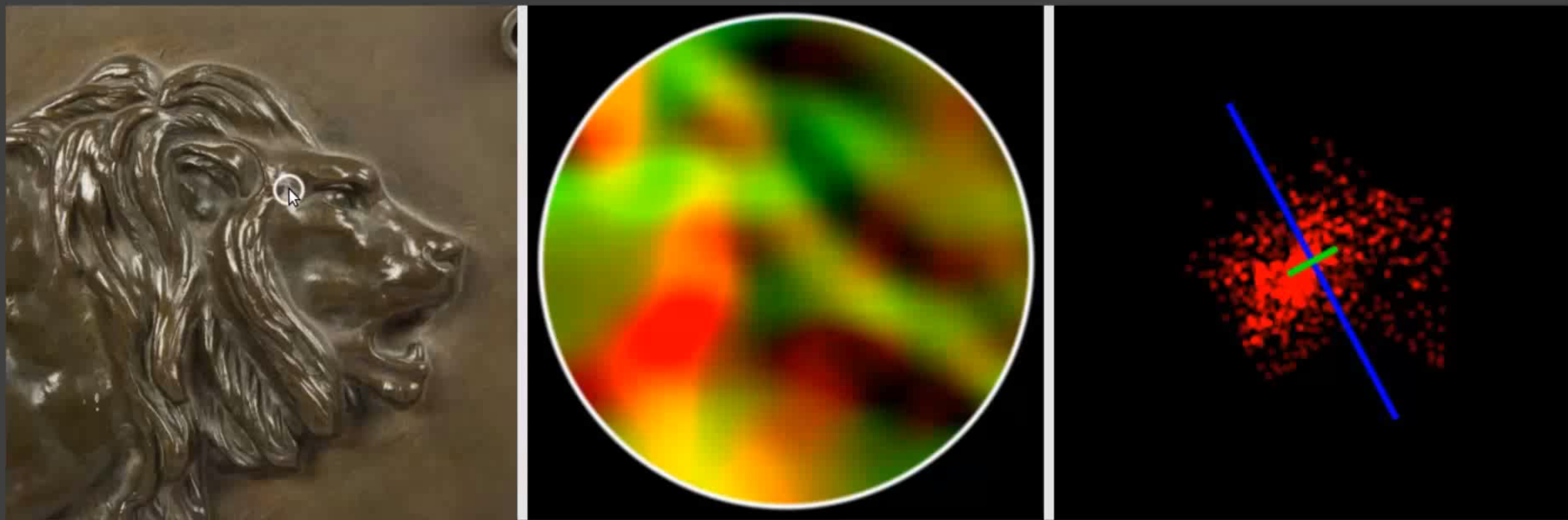
  [Dekel et al. 2015] [Bousseau et al. 2009] [Yeung et al. 2011]
- 3D Reconstruction
- [Khan et al. 2006] [Guttierrez et al. 2008] [Luft et al. 2006] [Kholgade et al. 2014] [Vergne et al. 2012]
- Shape perception
- [Horn and Brooks 1989] [Oren and Nayar 1997] [Koenderink and van Doorn 1980] [Fleming et al. 2004] [Fleming et al. 2011] [Caniard and Fleming 2007] [Mooney and Anderson 2014].

How do we perceive shape?



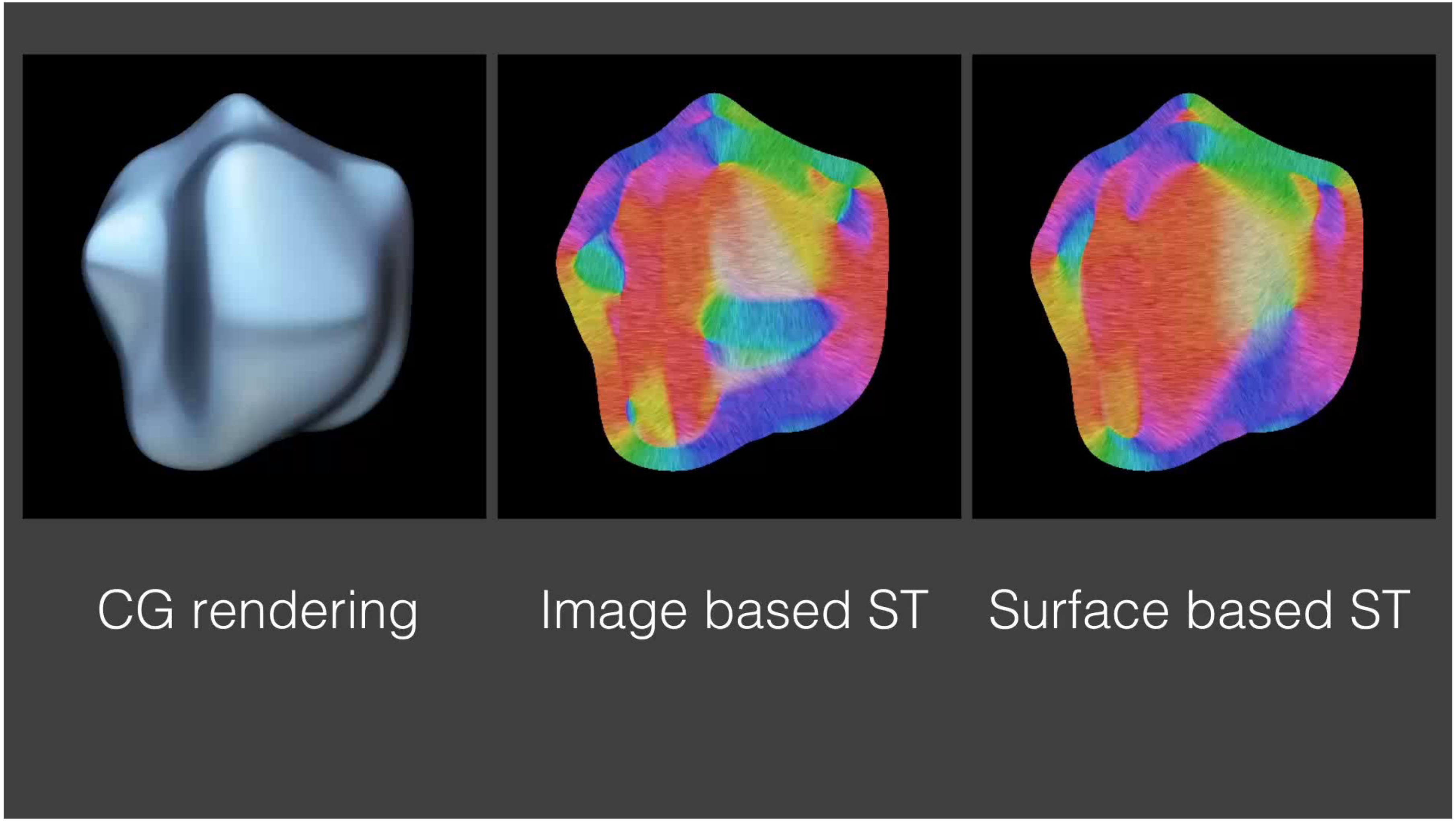
Measuring Orientation Patterns

Orientation patterns are measured by the structure tensor

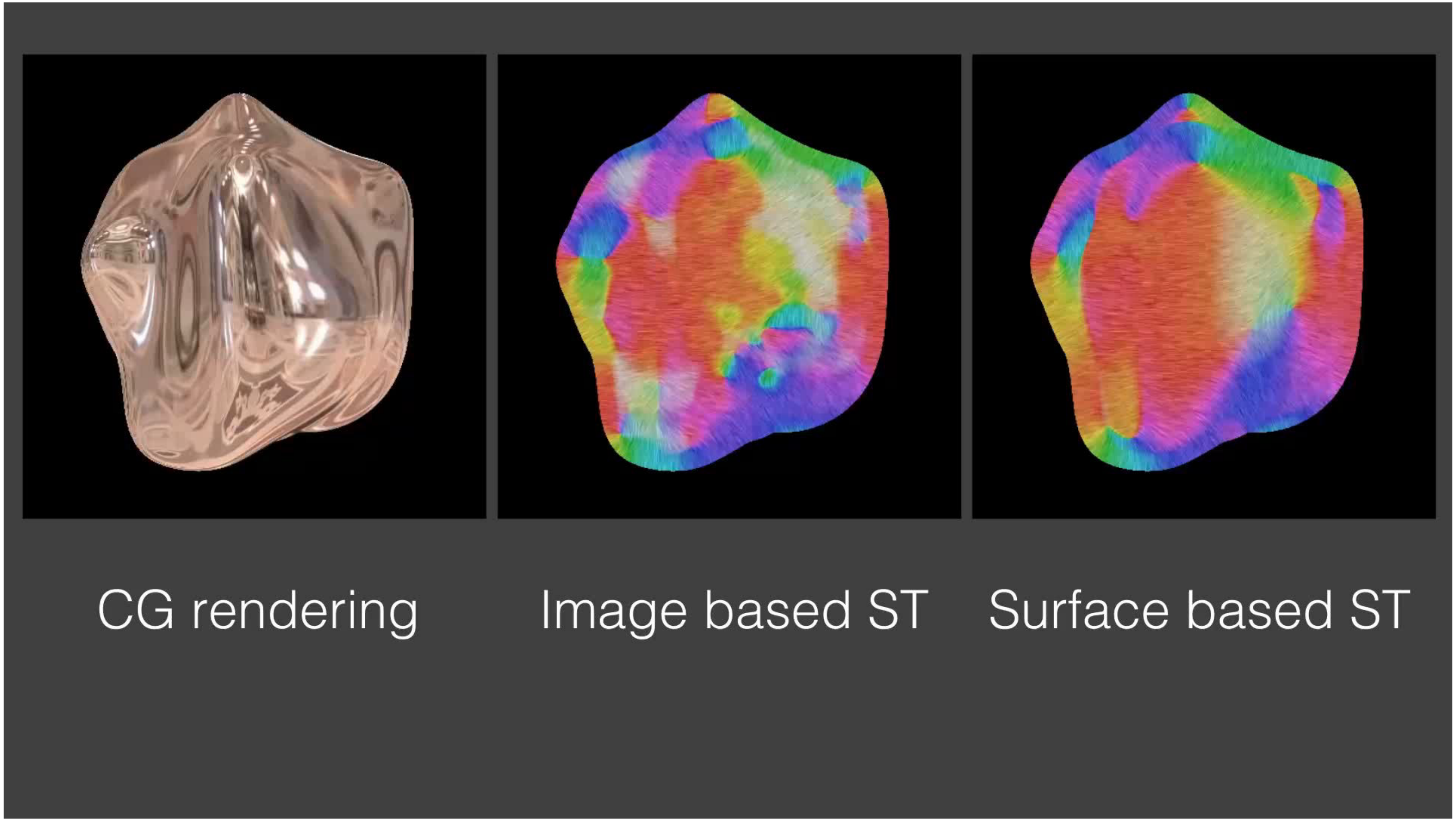


circle centered at pixel P	intensity gradients in circle	structure tensor at P

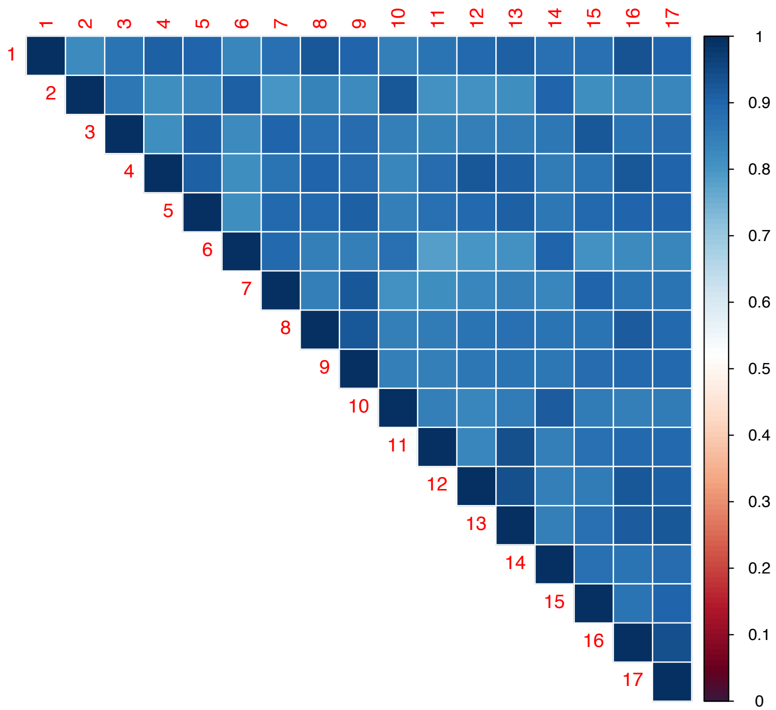
Surface ST vs Image ST



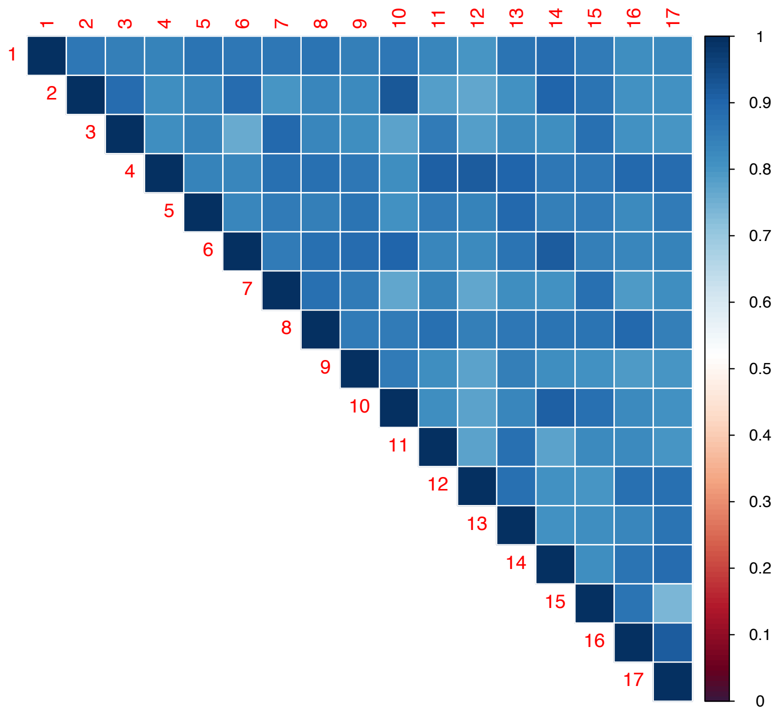
Shape ST vs Image ST



Shape ST vs Image ST correlation

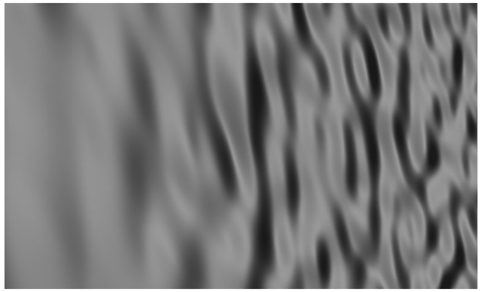


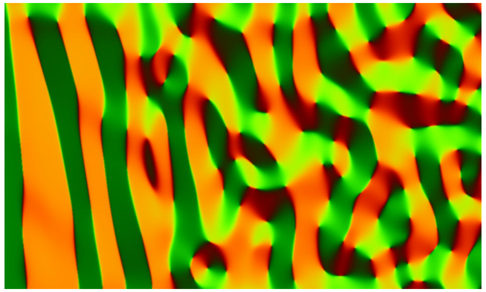
Direction



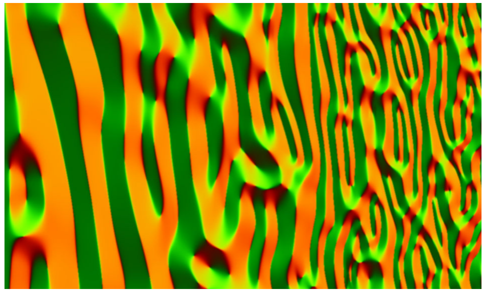
Max eigen value

Scale selection





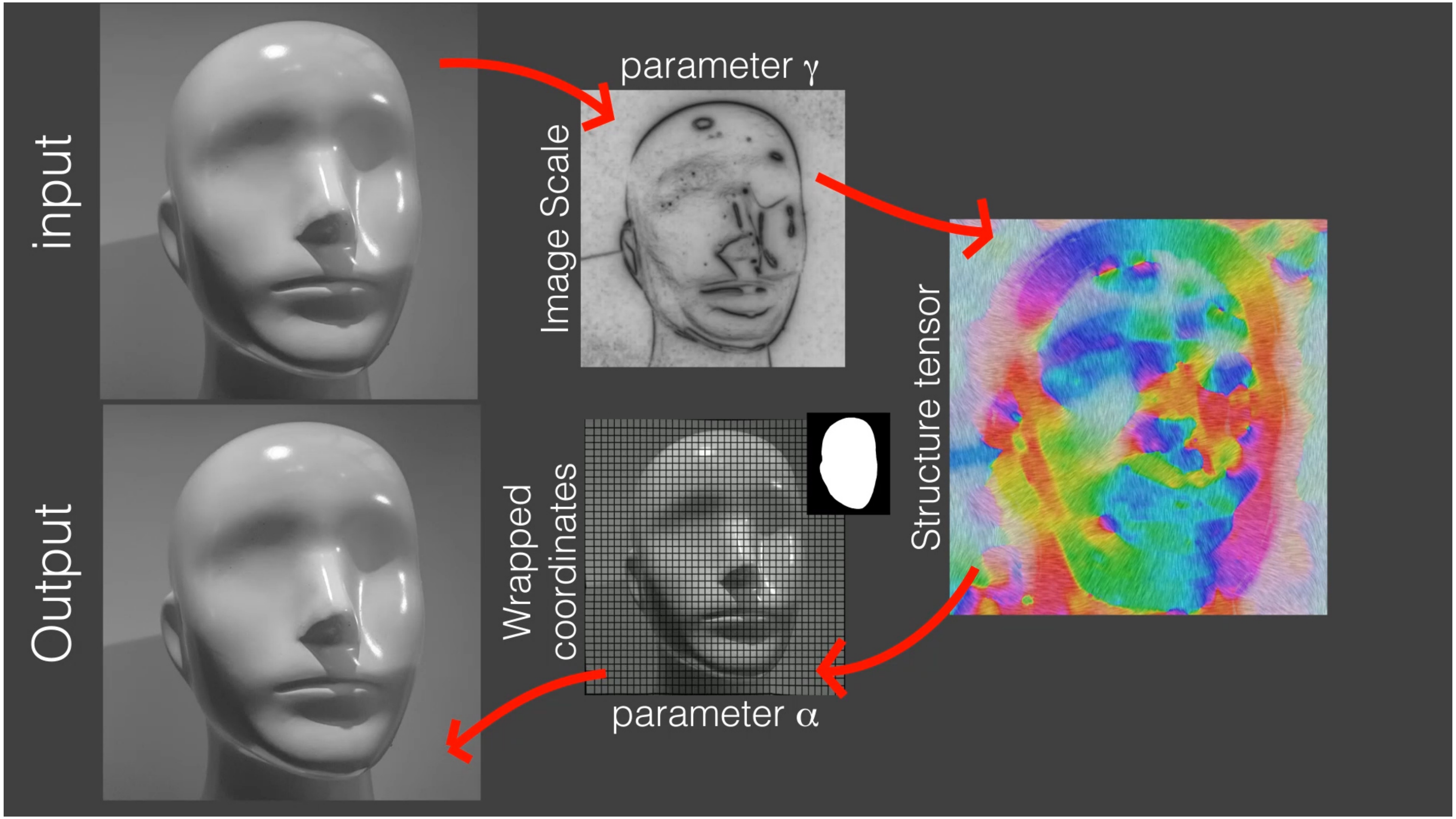
Uniform



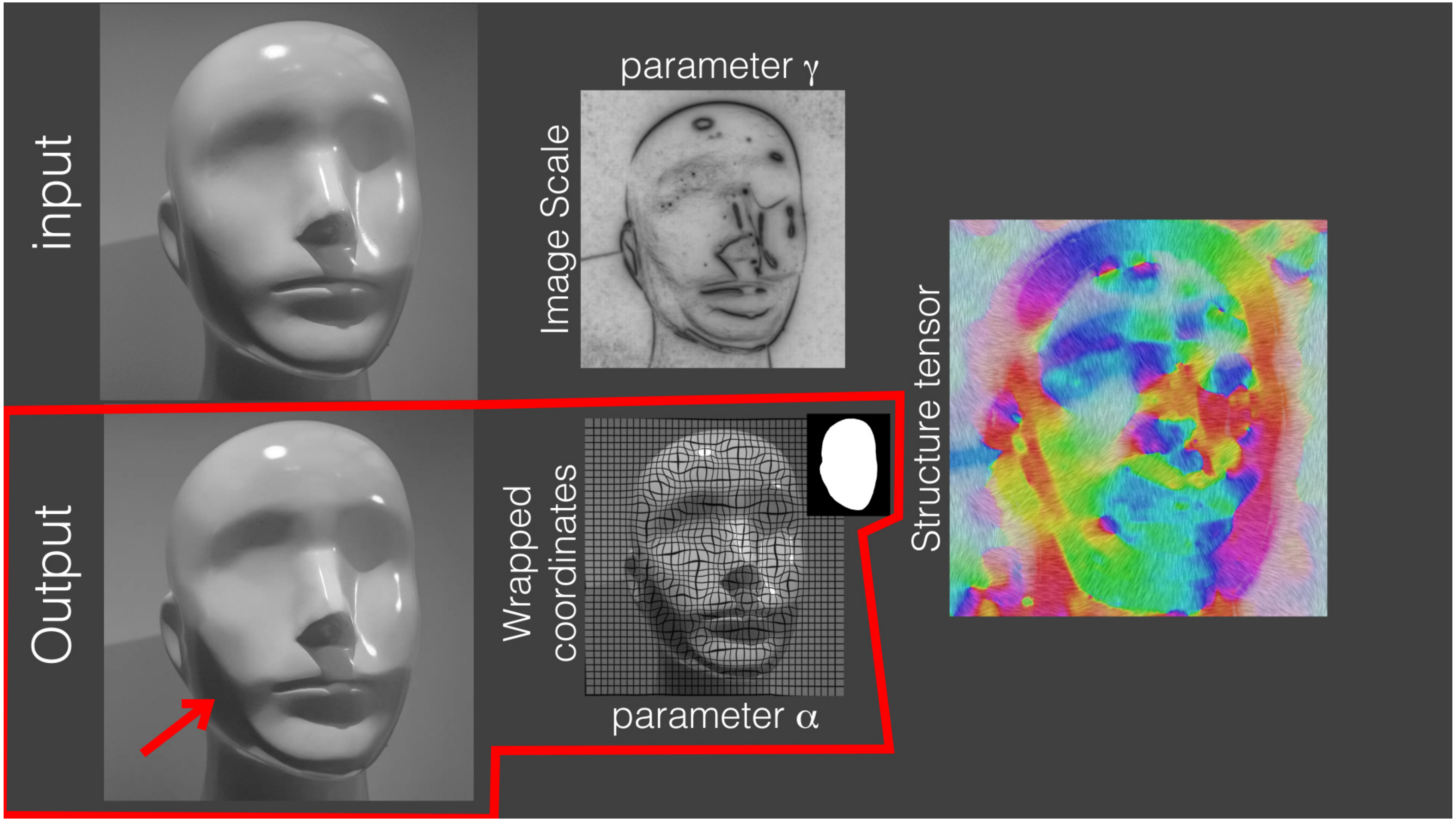
Local

$$\sigma_I(\mathbf{p},\gamma) = \frac{\int \sigma^{2\gamma}\, \beta_I(\mathbf{p},\sigma)\, d\sigma}{\int \beta_I(\mathbf{p},\sigma)\, d\sigma}$$

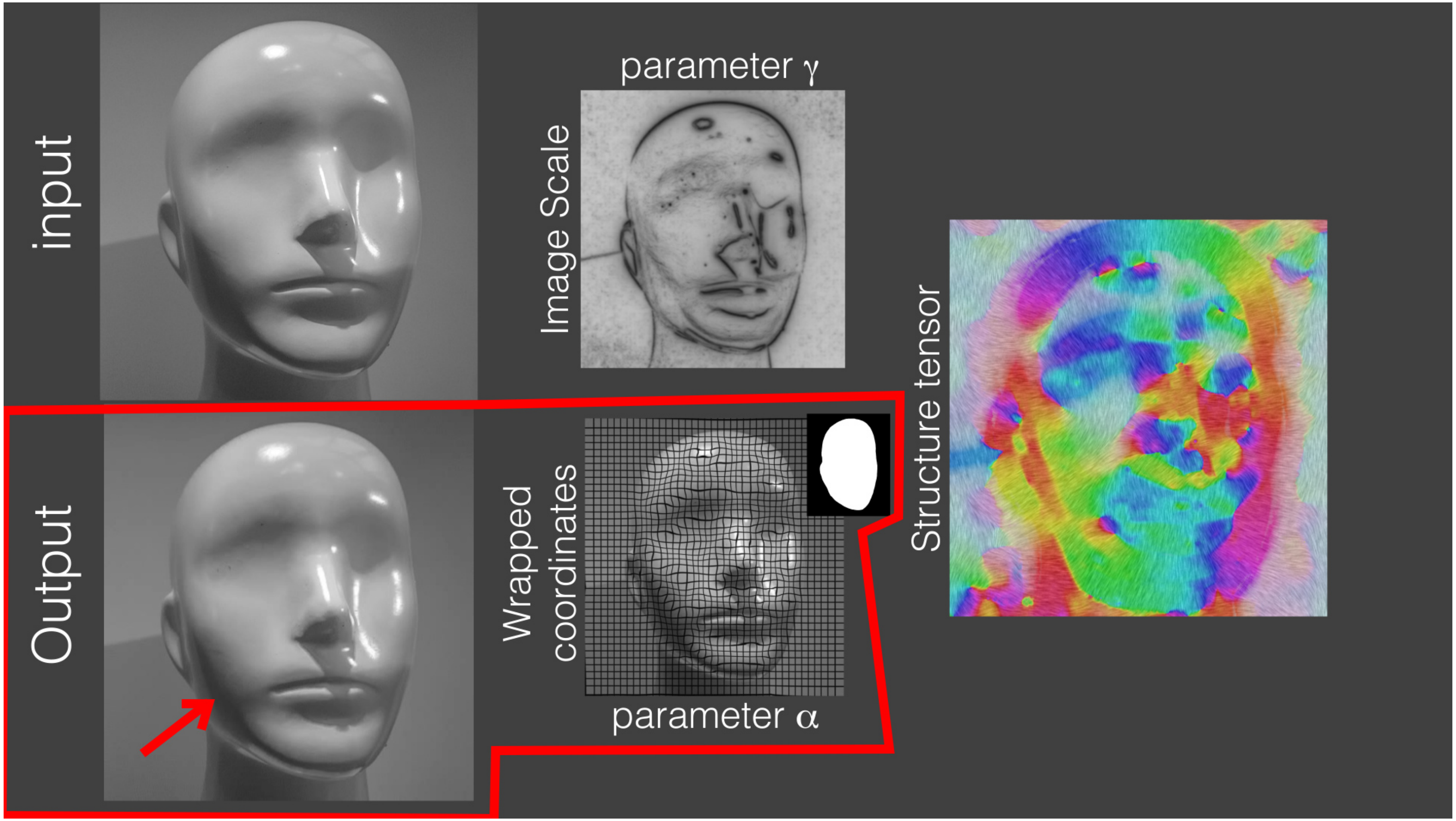
Warping pipeline



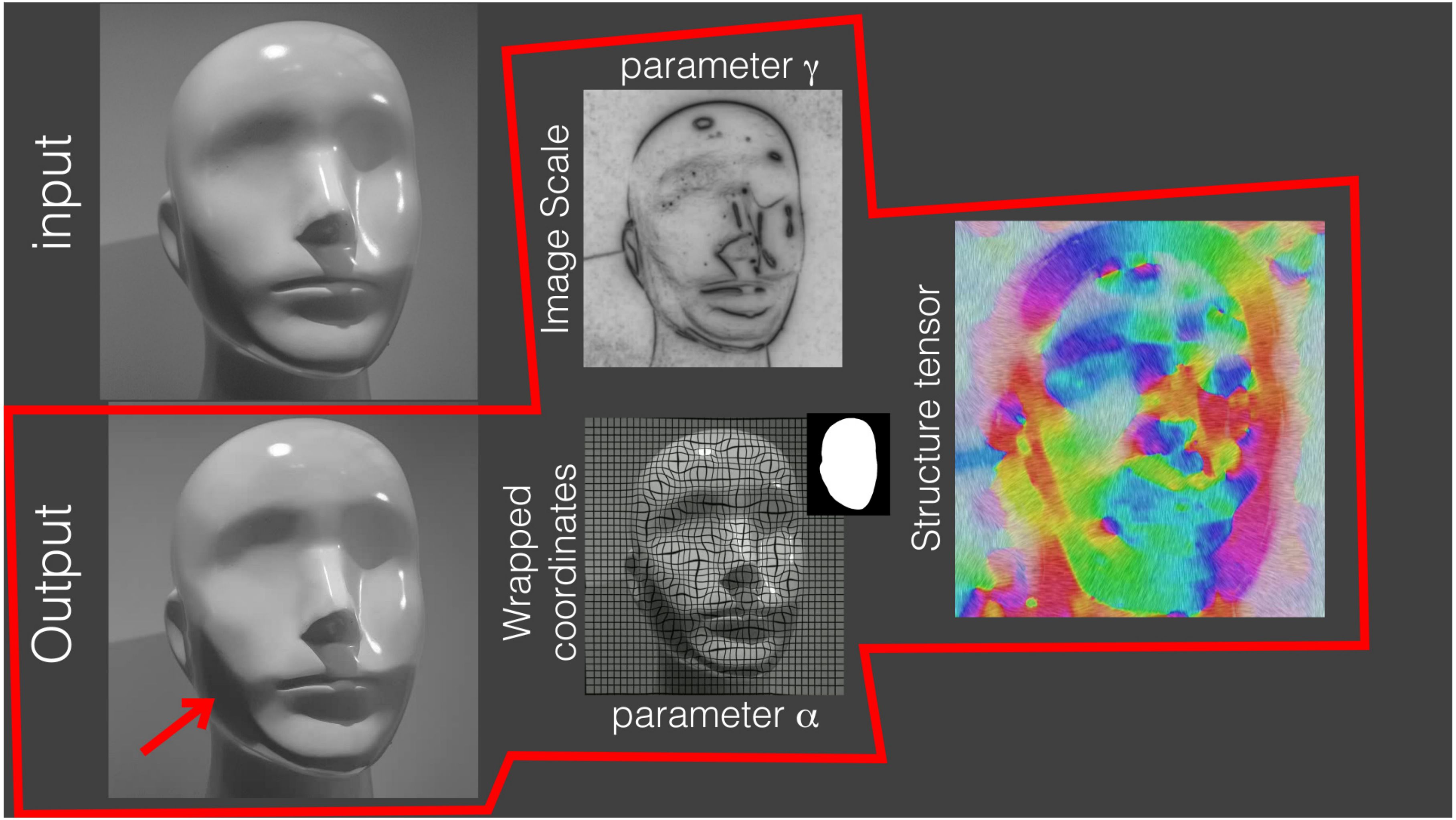
Sharpening: α = -1



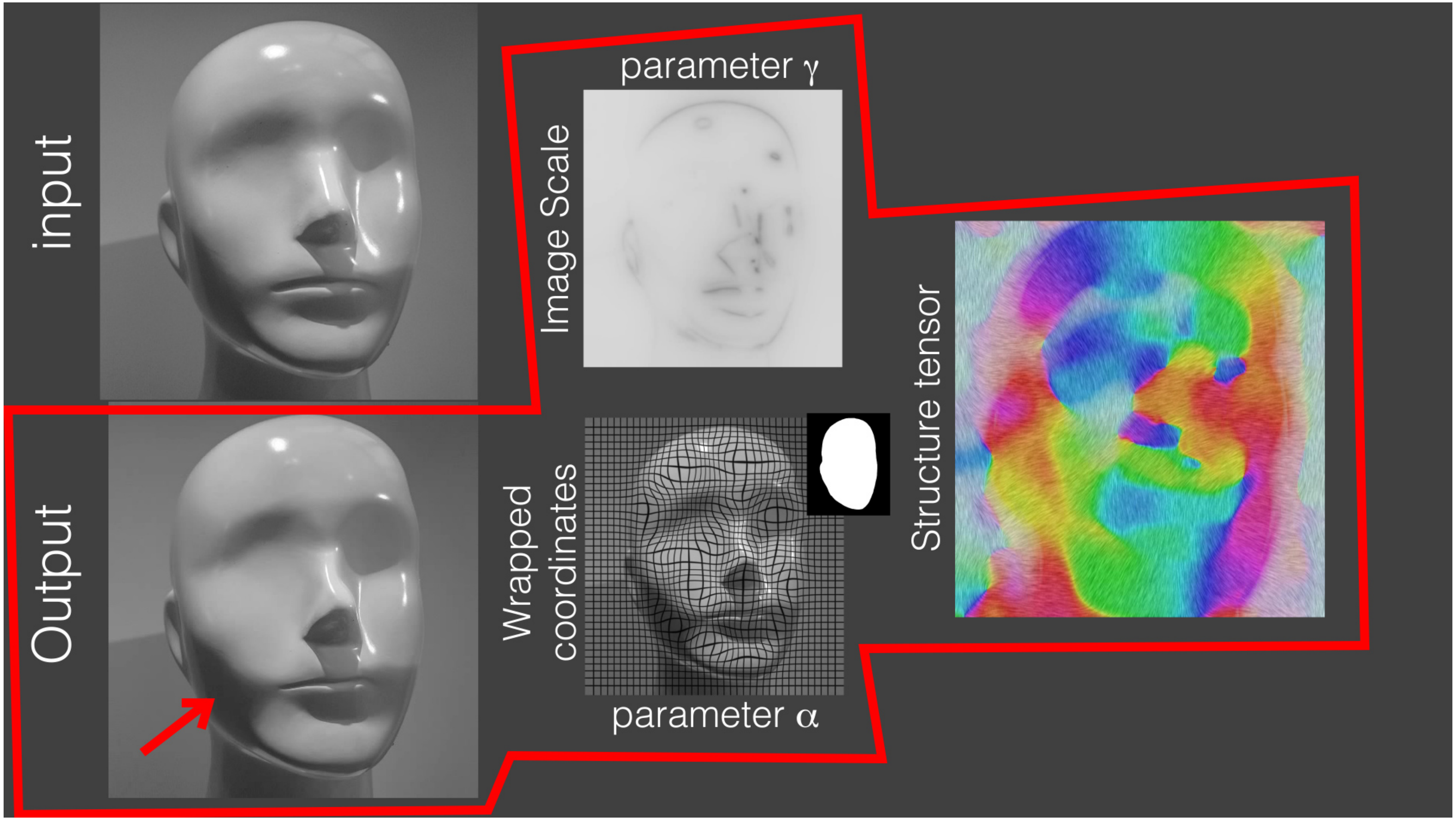
Rounding: $\alpha = 1$



Sharpening, small scale



Sharpening, large scale



User study

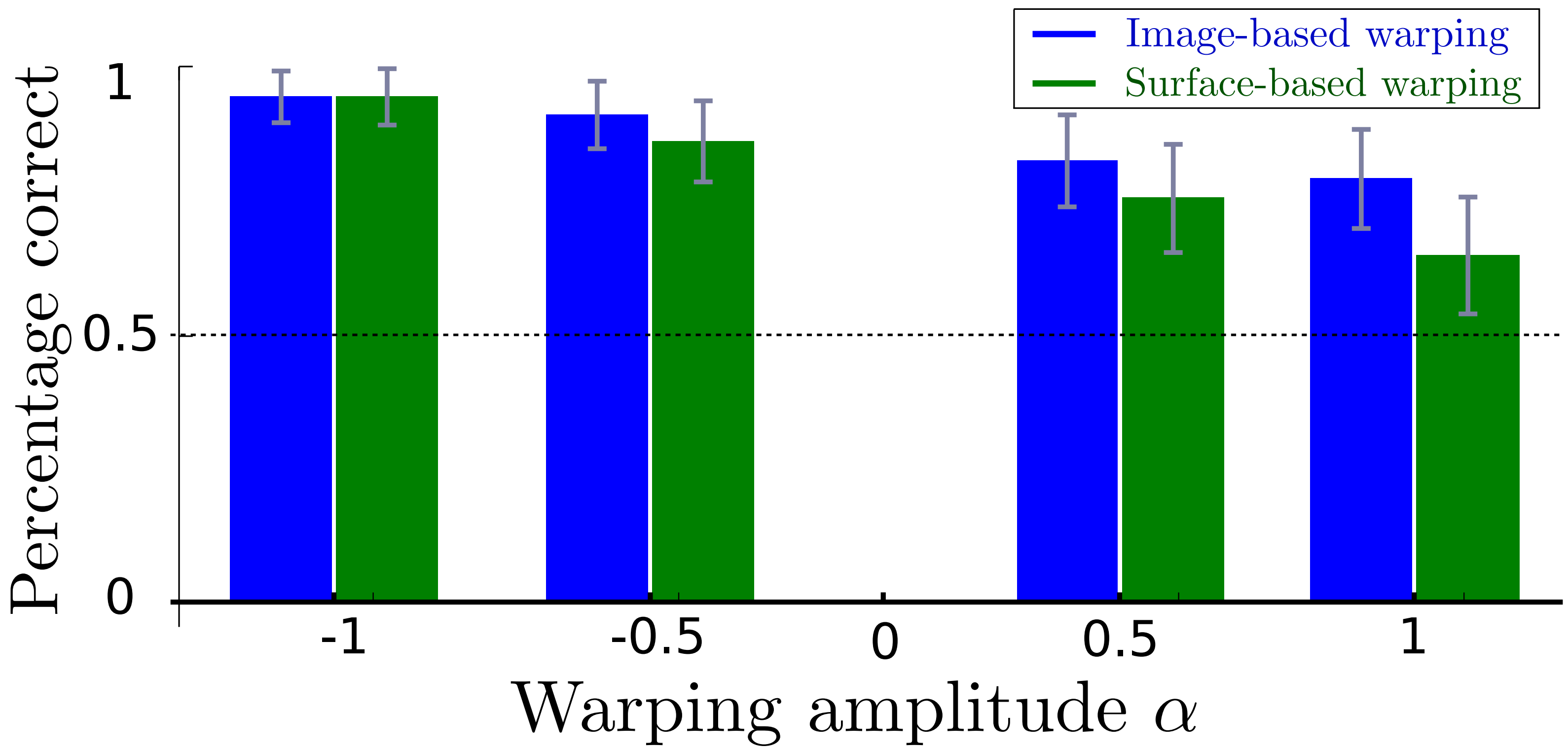


Image-based warping
Surface-based warping
Percentage correct
1
0.5
0
-1
-0.5
0
0.5
1
Warping amplitude α

Results

Conclusion

Perception issues in Visualization

- Perception of Depth – Application to DVR evaluation
- Perception of Noise – Application to Uncertainty Vis.
- Perception of Shape – Application to Image manipulation

In this talk: low level visual perception issues

- cognitive levels much more difficult

Take away message: perception matters!