Perceptually-driven Computational Displays

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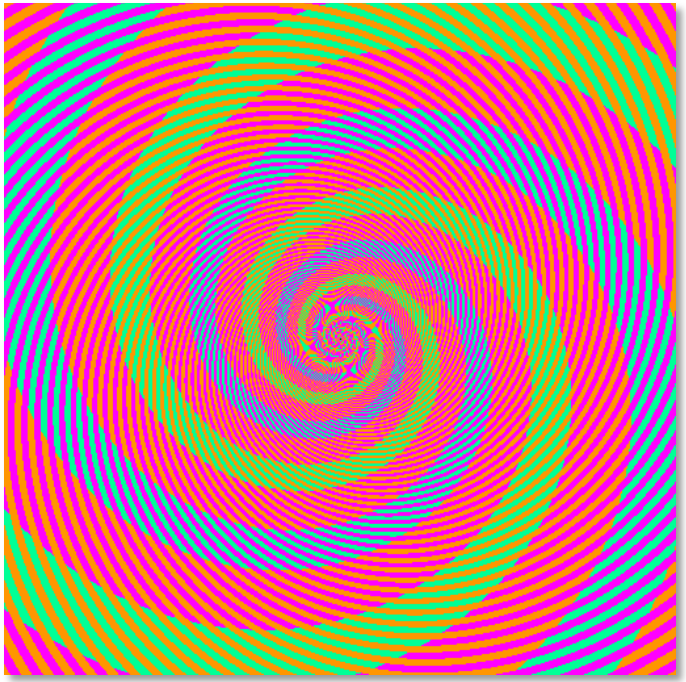
SIGGRAPH2012

- For the latest version of the slides, please go to:
  - http://giga.cps.unizar.es/~diegog/pub.html

The HVS is not perfect…



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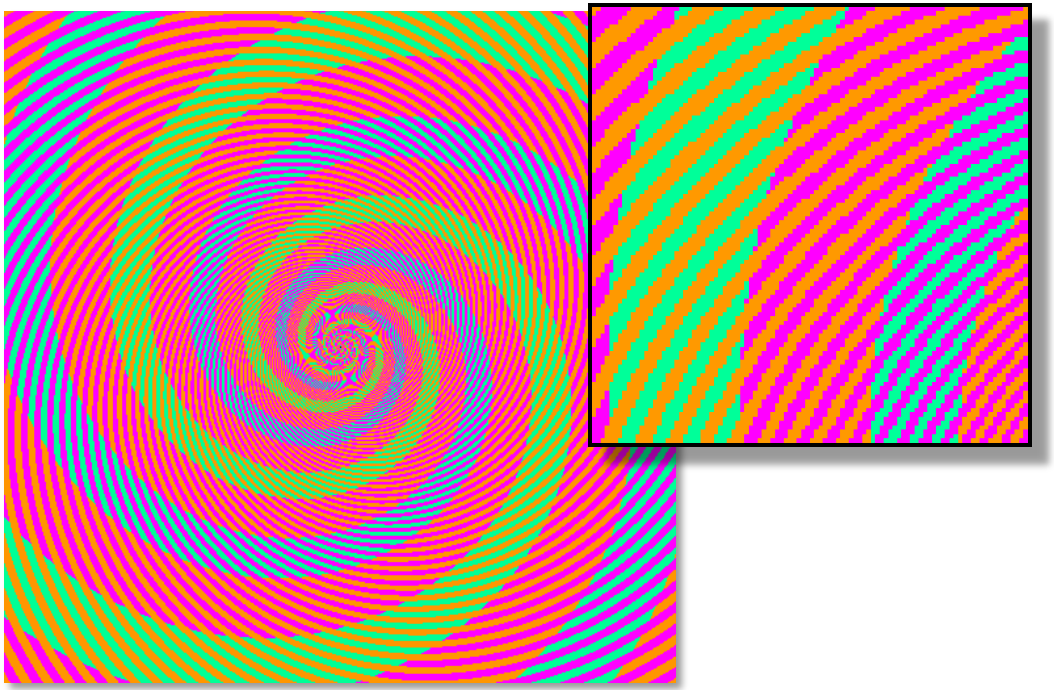

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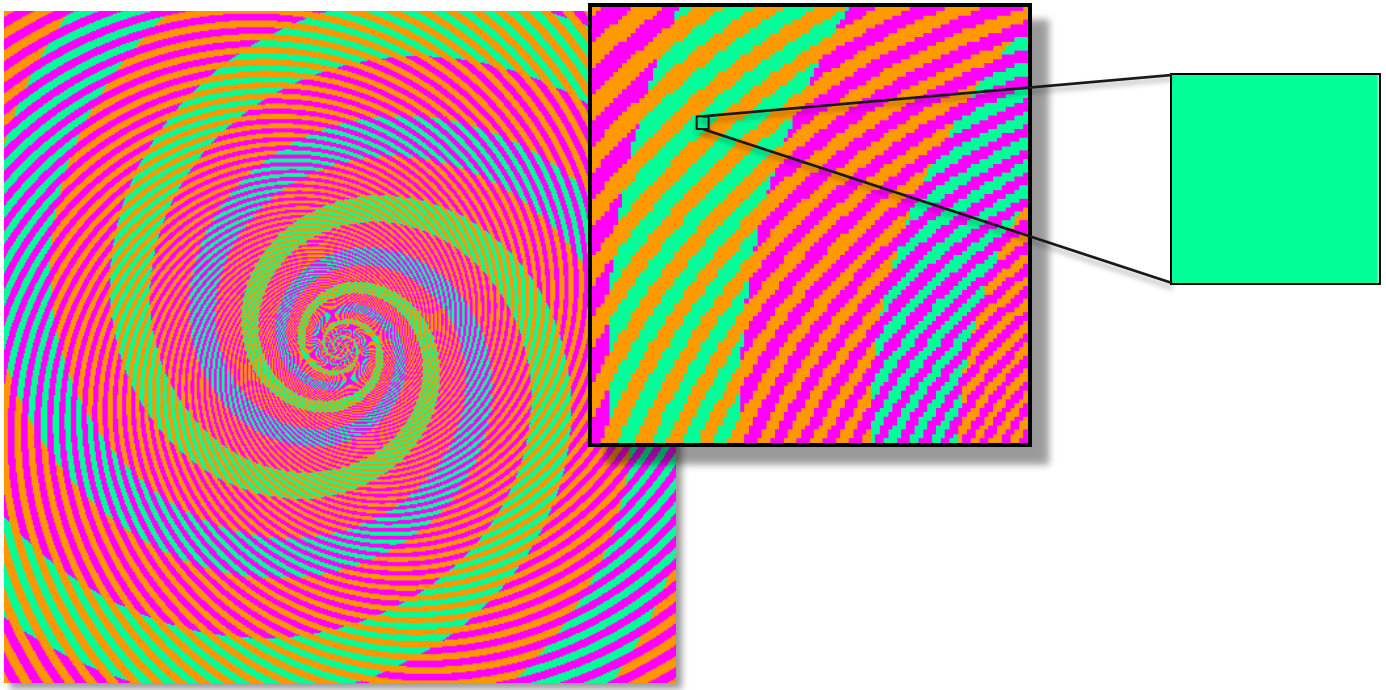

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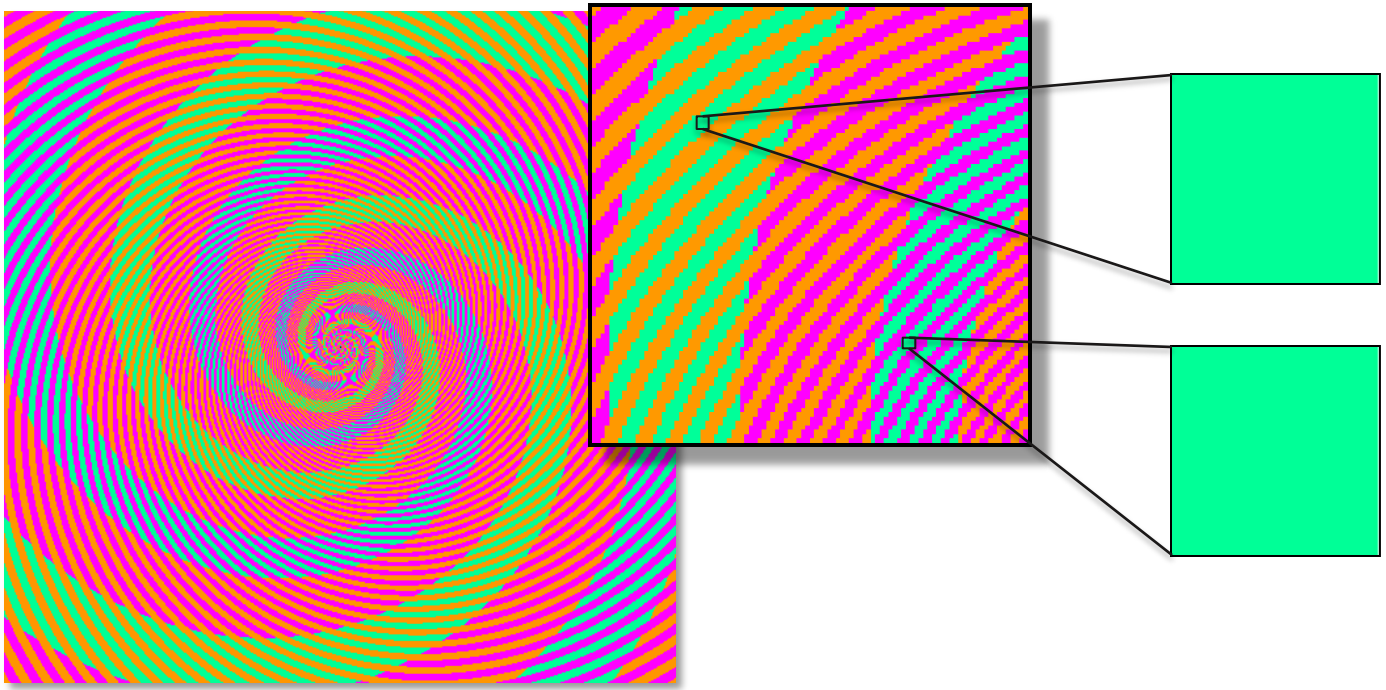

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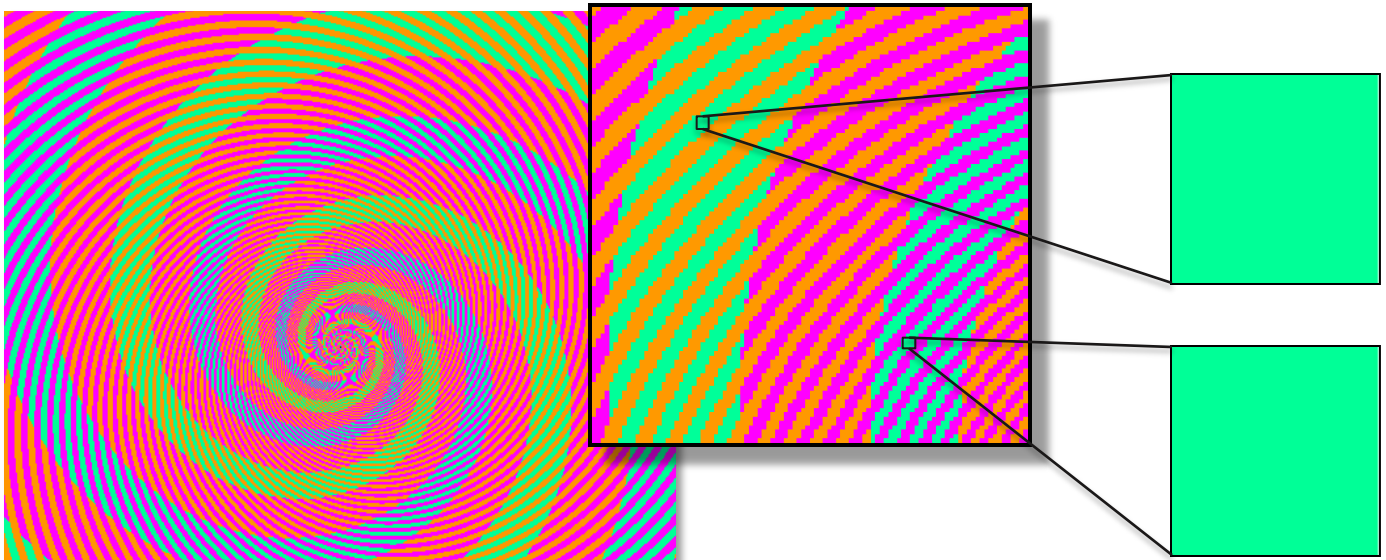


We judge the color of an object by comparing it to surrounding colors!

http://blogs.discovermagazine.com/badastronomy/2009/06/24/the-blue-and-the-green/

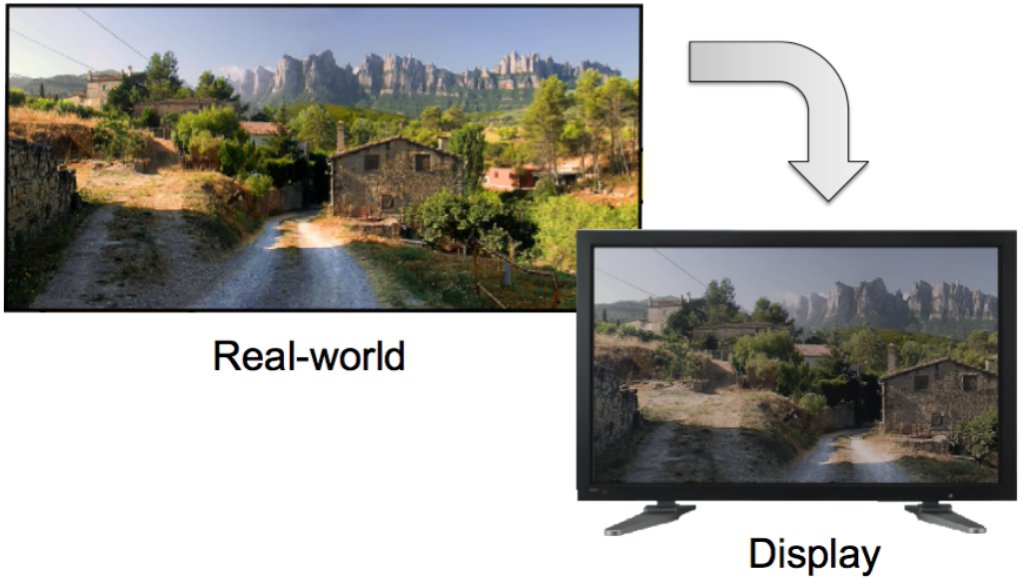
The HVS is not perfect…

- Color versions of White's effect (mechanism unknown)

The HVS is not perfect…

- The human visual system works in a specific way
  - Some aspects known, some are still open problems
- Sometimes what we *think* we see is different from the input signal

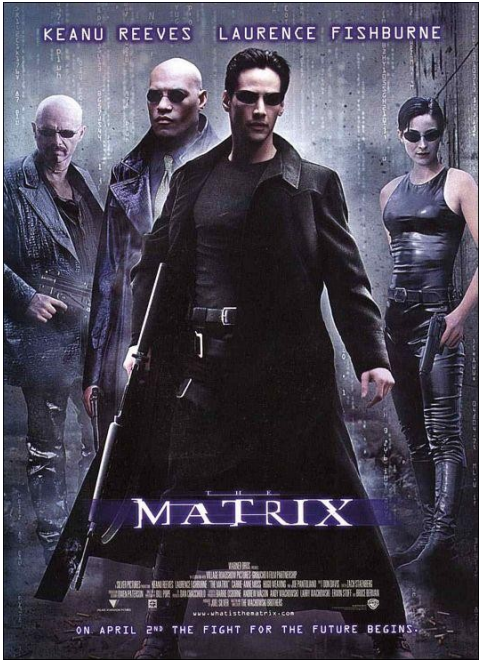
Color and tone mapping



Goal: map colors to a restricted color space

Multidimensional image retargeting, SIGGRAPH Asia 2011 (slide by Rafal Mantiuk)

Artists know this well: dynamic range



The art and science of depiction (Fredo Durand)

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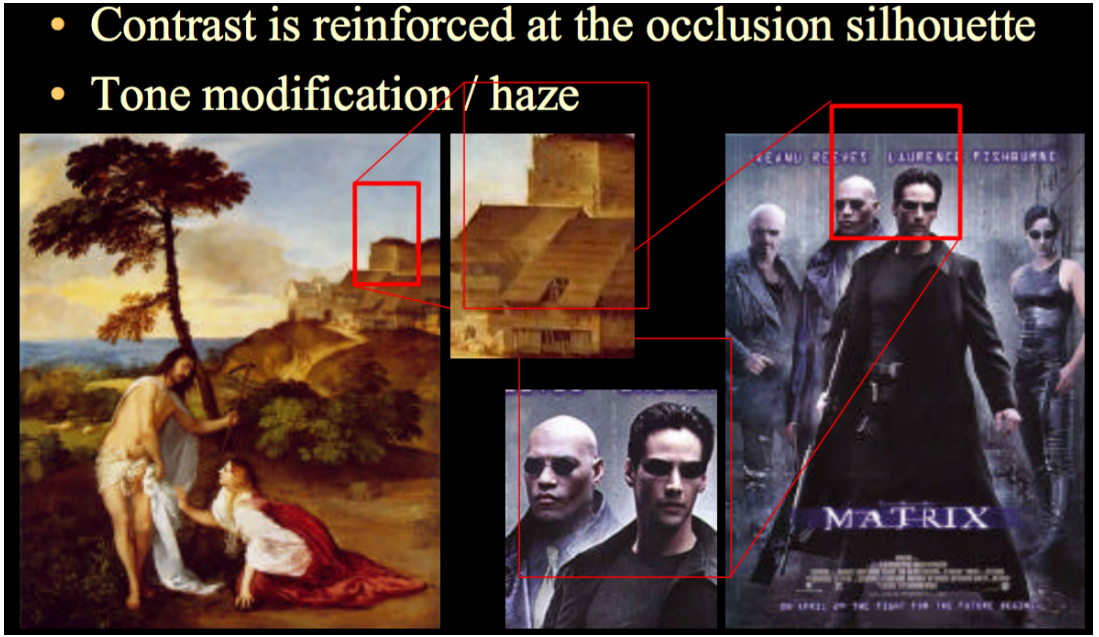

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The HVS is not perfect…

- The human visual system works in a specific way
  - Some aspects known, some are still open problems
- Sometimes what we *think* we see is different from the input signal
- **Let's take that into account when designing displays!**

Displays are limited too

- Dynamic range
- Color
- Depth
- Spatial frequencies
- Temporal frequencies
- …

Computational displays

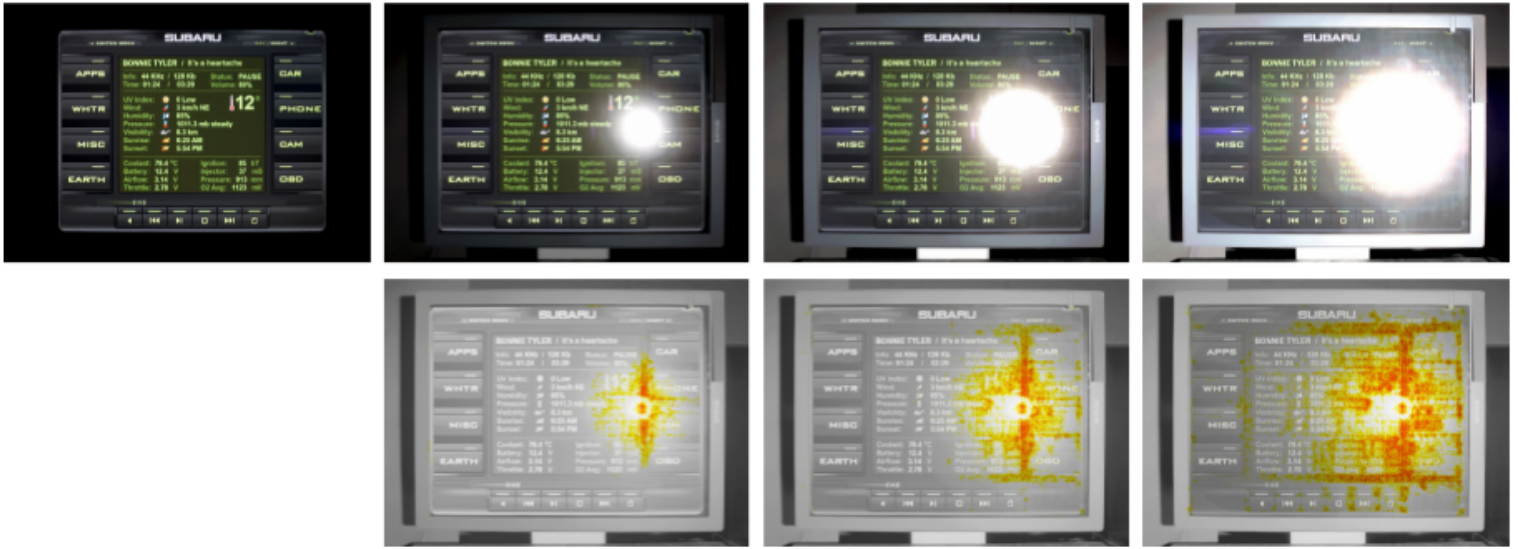
- Dynamic range
- Color
- Depth
- Spatial frequencies
- Temporal frequencies
- …

- Can we exploit the limitations/mechanisms of the HVS to enhance their **perceived** capabilities?

A toy example: visual masking

Human visual system models in computer graphics (Tunç Aydın, PhD Thesis 2010)

Another example: display visibility



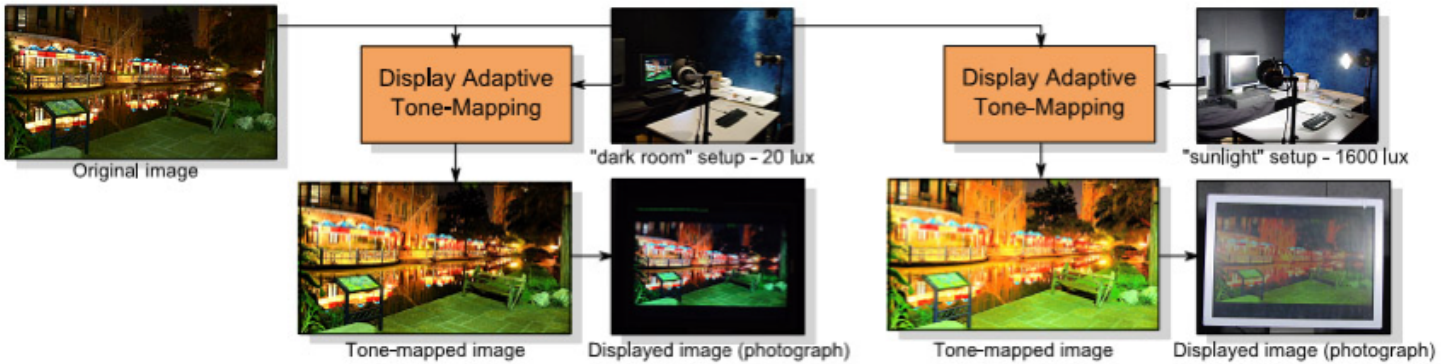
Predicting display visibility under dynamically changing lighting conditions, Eurographics 2009 [Tunç Aydın et al.]

Dynamic range and tone mapping

Goal: map colors to a restricted color space

Multidimensional image retargeting, SIGGRAPH Asia 2011 (slide by Rafal Mantiuk)

Different viewing conditions



Predict the visibility of contrast distortions, and alter the input so that they are minimized

Display adaptive tone mapping, SIGGRAPH 2008 [Mantiuk et al.]

Different viewing conditions

Dark room

Display adaptive tone mapping, SIGGRAPH 2008 [Mantiuk et al.]

Different viewing conditions

Bright office

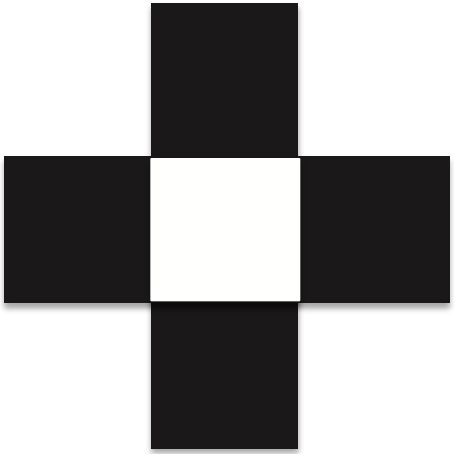
Display adaptive tone mapping, SIGGRAPH 2008 [Mantiuk et al.]

Different viewing conditions

Outdoors

Display adaptive tone mapping, SIGGRAPH 2008 [Mantiuk et al.]

Apparent brightness



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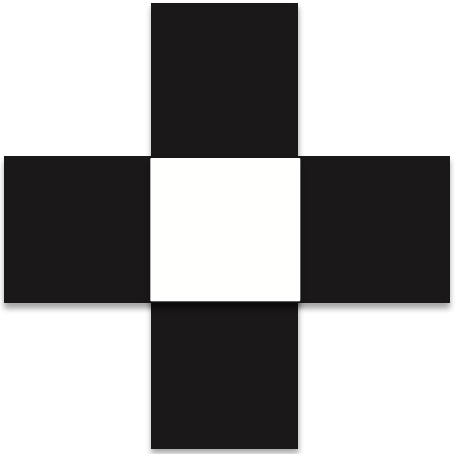
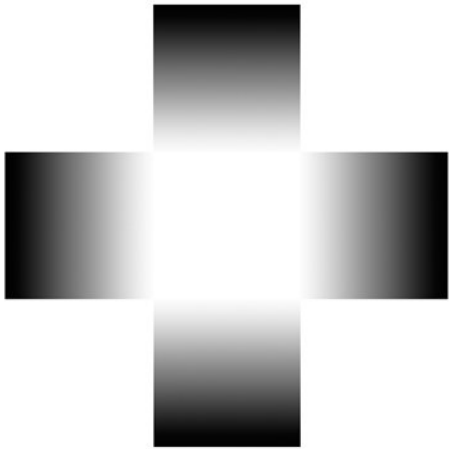
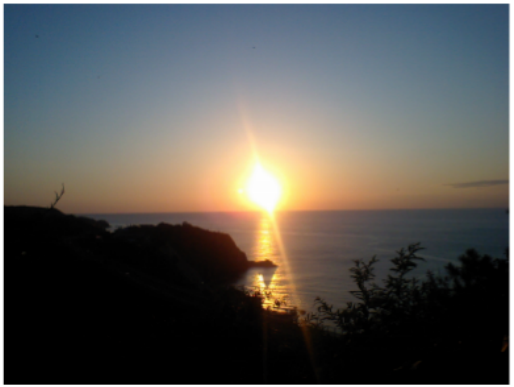




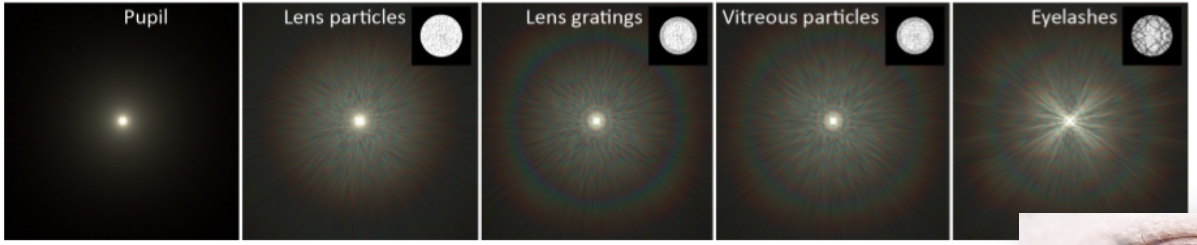
http://www.opticalillusion.net/optical-illusions/grey-glow-illusion-the-glare-effect/

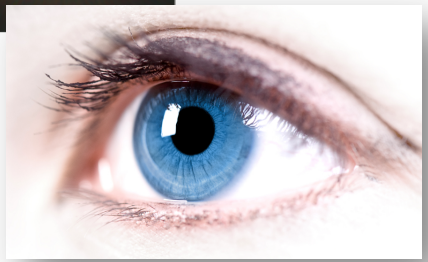
Apparent brightness



Brightness of the glare illusion. APGV 2008 [Yoshida et al.]

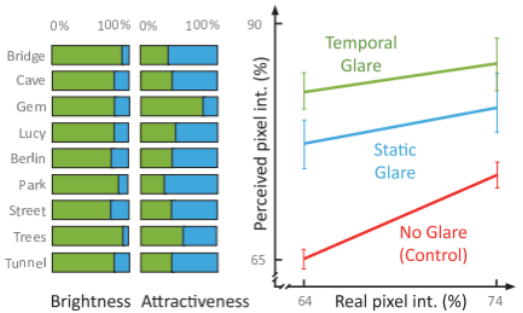
Dynamic glare





Temporal Glare: Real-Time Dynamic Simulation of the Scattering in the Human Eye, Eurographics 2009 [Ritschel et al.]

Dynamic glare



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Apparent brightness

Perception-based rendering: eyes wide bleached, Eurographics 2005 [Gutierrez et al.]

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- Neurons in the retina habituate **(adapt)** and stop responding to a fixed stimulus
- Once adapted, they need a little time to reset to their original, responsive state

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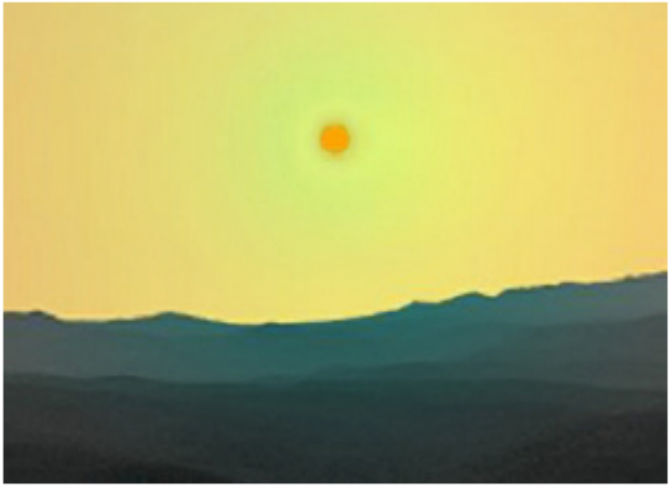

bleaching of retinal photoreceptors

Perception-based rendering: eyes wide bleached, Eurographics 2005 [Gutierrez et al.]

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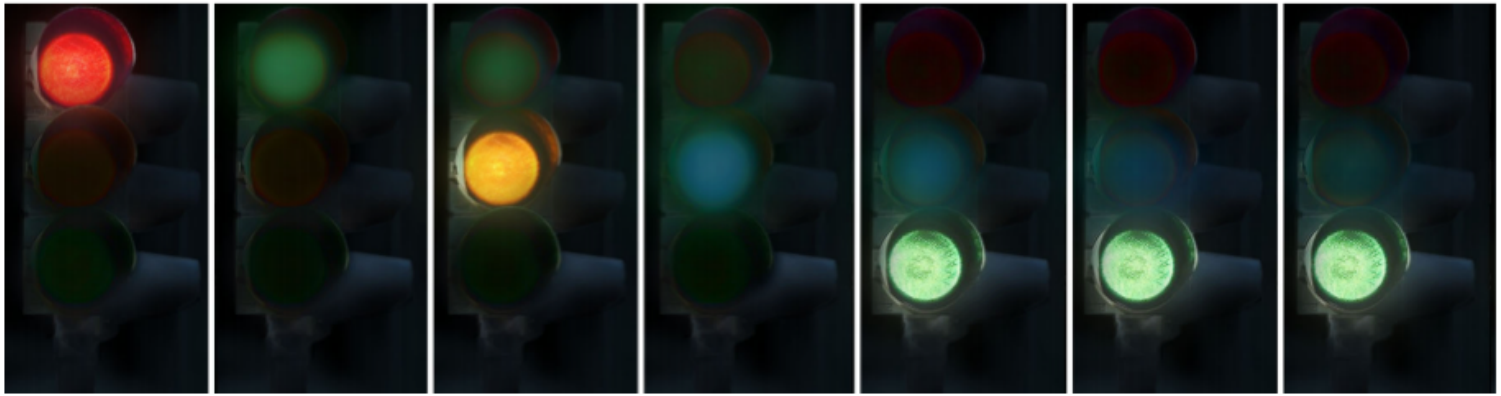
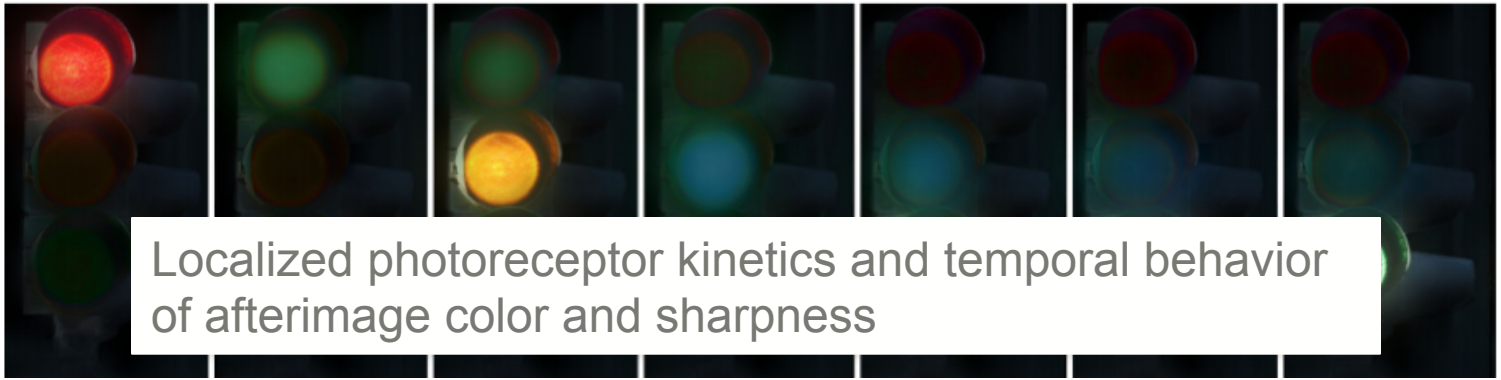
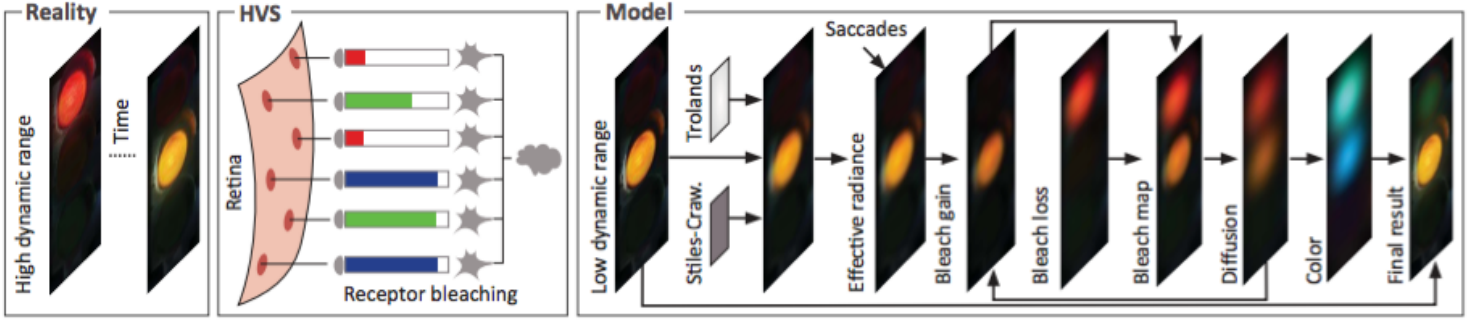


A computational model of afterimages, Eurographics 2012 [Ritschel and Eisemann]

Apparent brightness



Localized photoreceptor kinetics and temporal behavior of afterimage color and sharpness



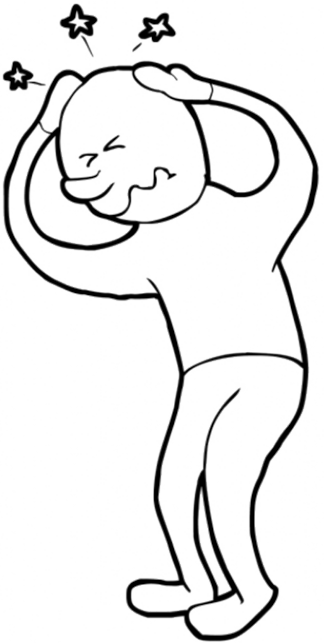
Apparent brightness

“Unsharp masking, countershading and halos: enhancements or artifacts?” by Trentacoste et al. 2012

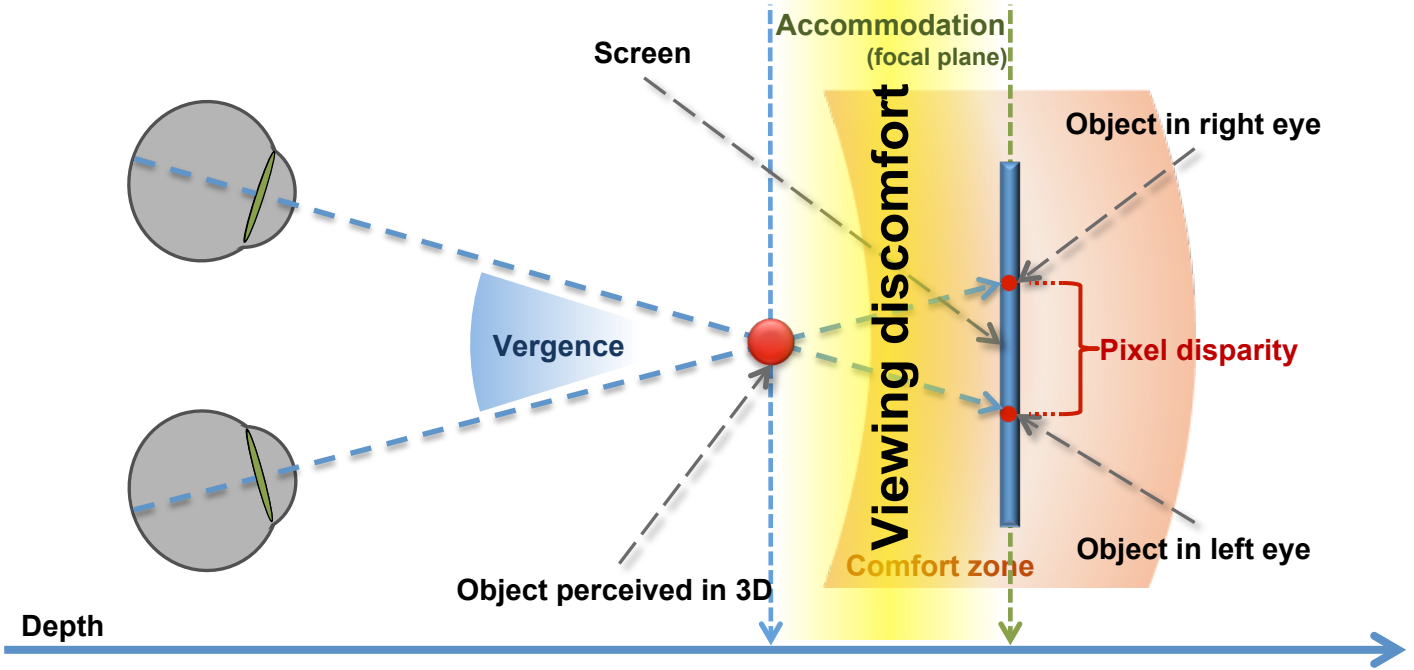
Stereo

Stereo Retargeting

Stereo Retargeting



Visual Discomfort



A perceptual model for disparity, SIGGRAPH 2011 [Didyk et al.]

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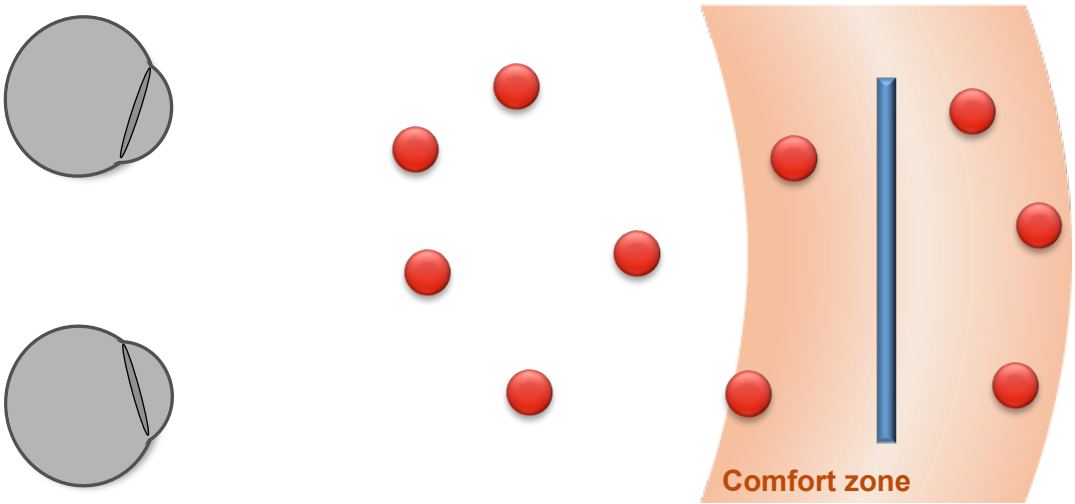

Scene manipulation → Viewing comfort

~~Viewing discomfort~~

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Disparity Remapping

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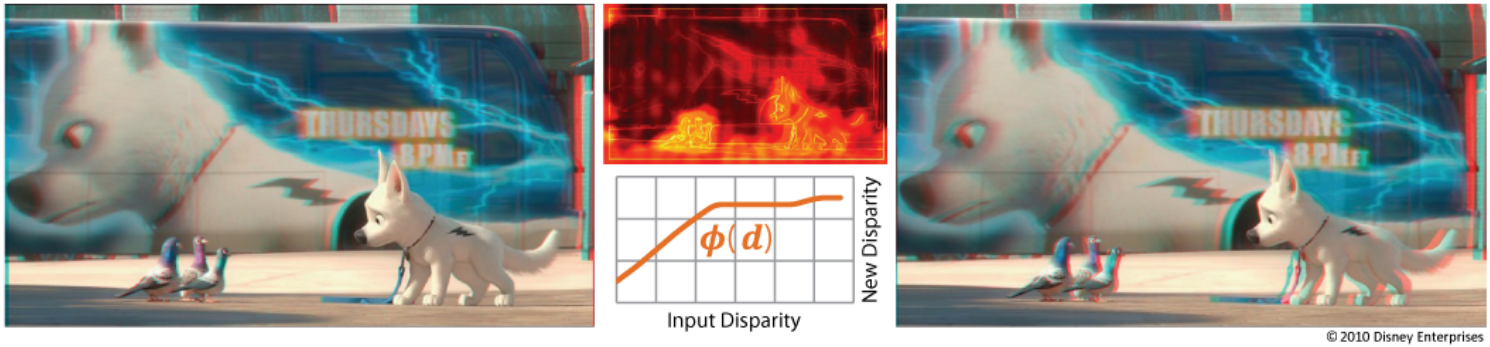
Disparity Remapping

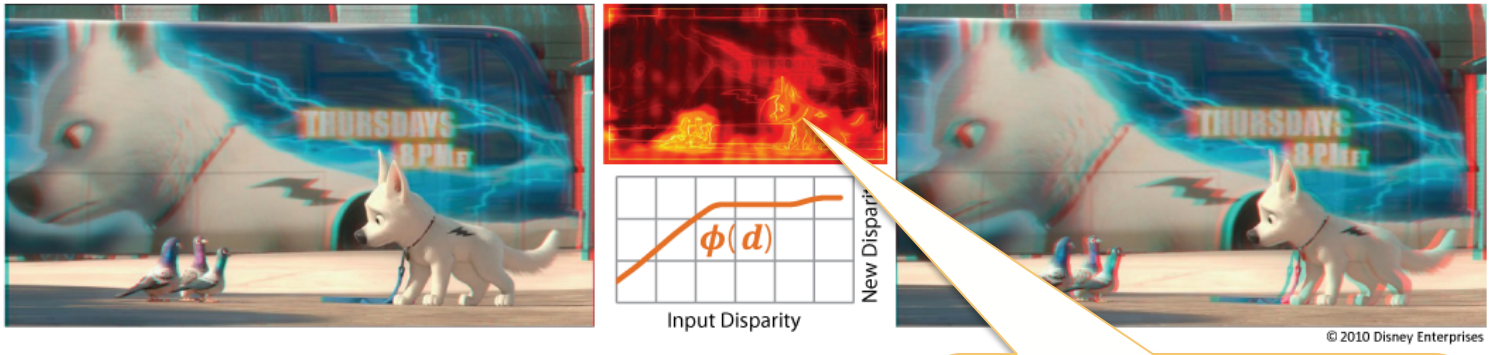


Nonlinear disparity retargeting

Introduce more distortions where they will be less perceived

"Nonlinear Disparity Mapping for Stereoscopic 3D" by Lang et al. 2010

Disparity Remapping



Visual Importance based on saliency

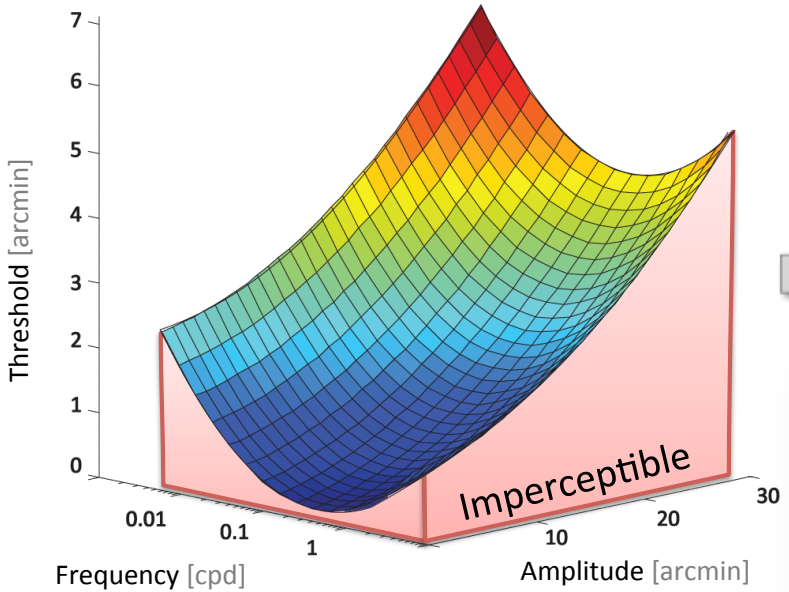
"Nonlinear Disparity Mapping for Stereoscopic 3D" by Lang et al. 2010

Disparity Remapping

Edge saliency + global texture saliency + disparity-based saliency

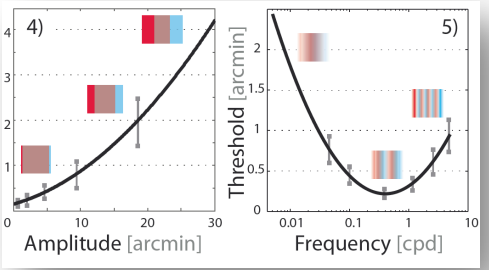
"Nonlinear Disparity Mapping for Stereoscopic 3D" by Lang et al. 2010

Disparity discrimination threshold function



Can be removed

Without reducing quality



A perceptual model for disparity, SIGGRAPH 2011 [Didyk et al.]

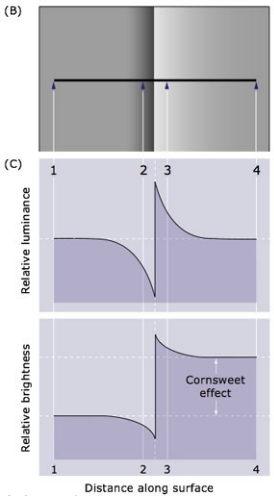
Perceptual linear space

- Scaling is performed in a **linear perceptual space**
- Different applications, including:
  - Compression: remove disparity below 1 JND (or more)
  - Non-linear disparity scaling: more predictable in linear space
  - “Backward compatible stereo”

A perceptual model for disparity, SIGGRAPH 2011 [Didyk et al.]

Backward-compatible stereo

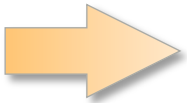
- Relies on the *Craik-O'Brien-Cornsweet* illusion
  - Apparent depth is **induced** at the disparity continuity, and **propagated** by the HVS

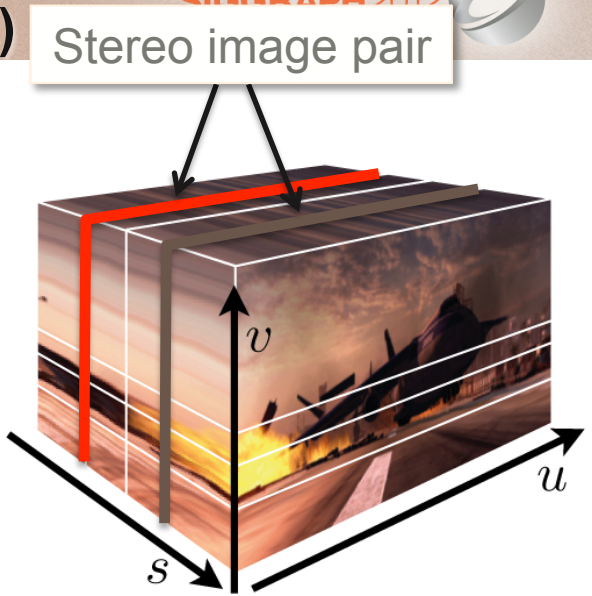


Cornsweet image from http://www.purveslab.net/

A perceptual model for disparity, SIGGRAPH 2011 [Didyk et al.]

Disparity Remapping (light fields)





Light Field

"Multi-Perspective Stereoscopy from Light Fields" by Kim et al. 2011

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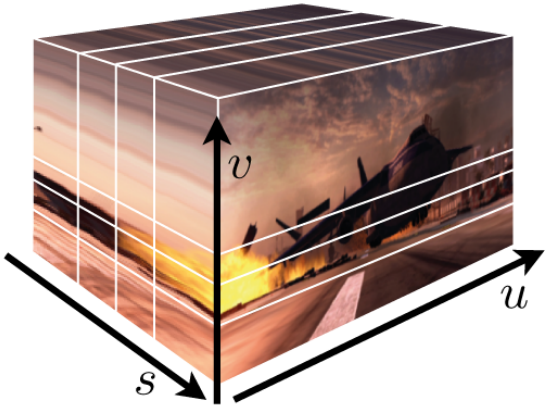

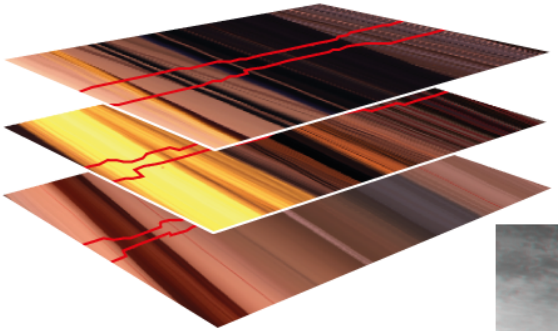

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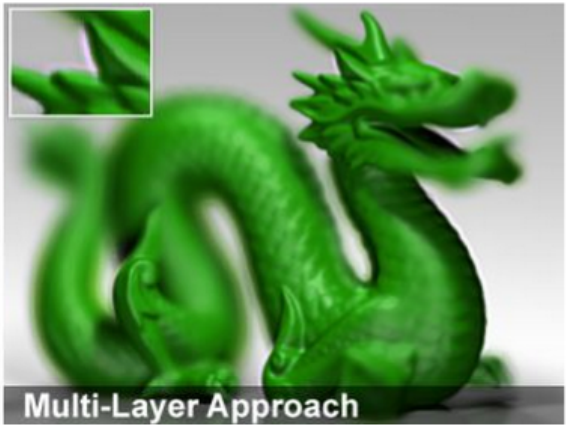
Automultiscopic displays

- Similar to DOF in photography, automultiscopic displays can only reproduce a limited depth range at full spatial resolution



Dragon from *Layered 3D: tomographic image synthesis for attenuation-based light field and high dynamic range displays,* SIGGRAPH 2011 [Wetzstein et al.]

Antialiasing for automultiscopic 3D displays, EGSR 2006 [Zwicker et al.]

Perceptually-based content remapping for automultiscopic displays, SIGGRAPH 2012 (poster) [Masia et al.]

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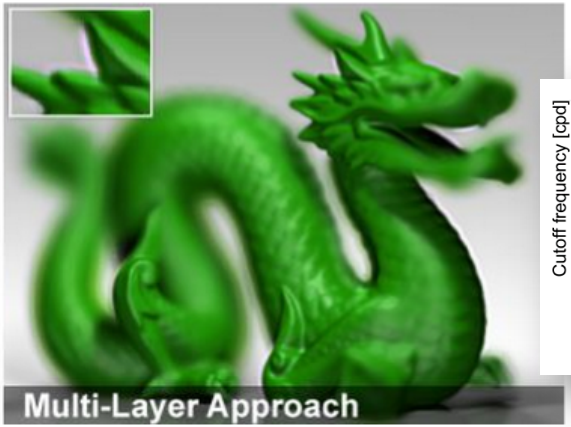

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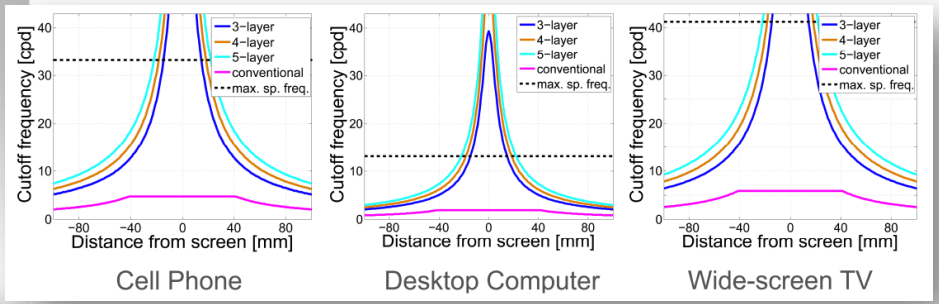

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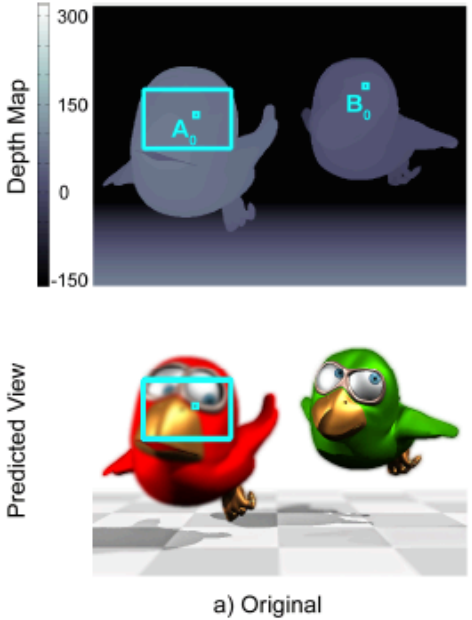
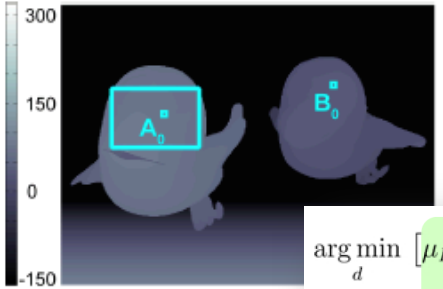


a) Original

Perceptually-based content remapping for automultiscopic displays, SIGGRAPH 2012 (poster) [Masia et al.]

Automultiscopic displays



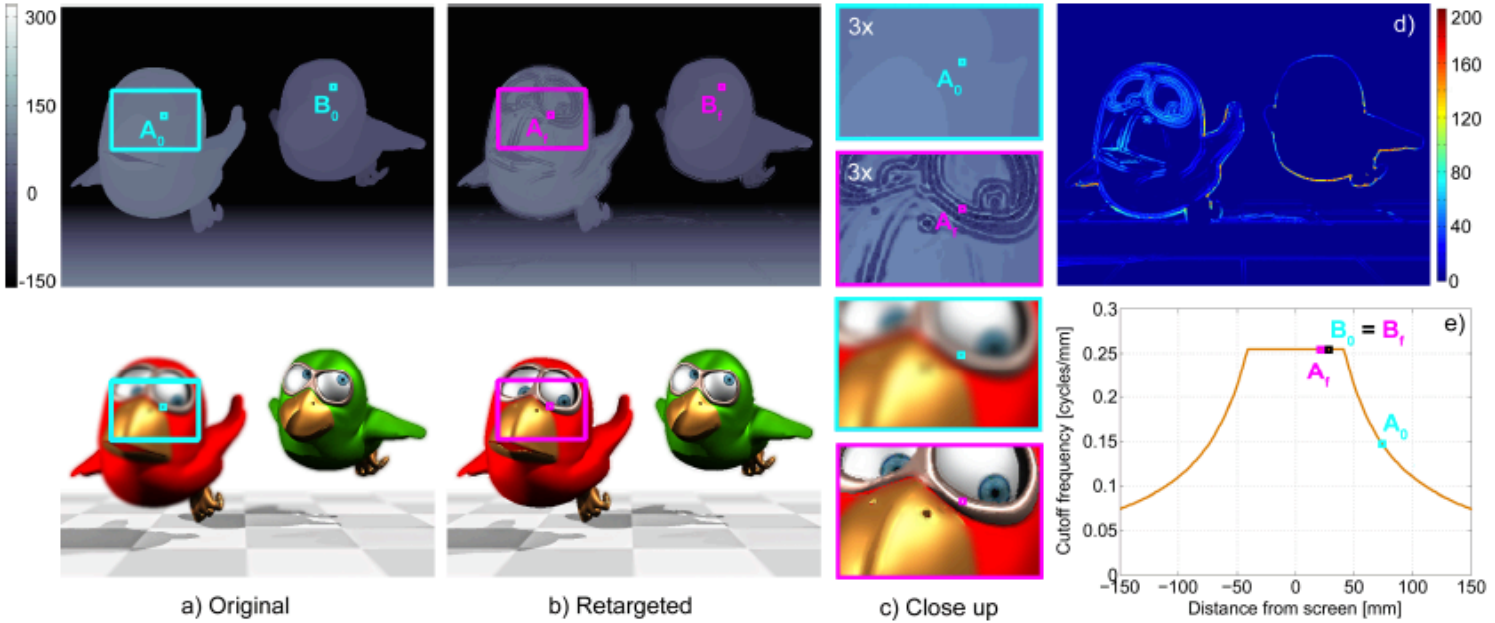
$$\arg\min_{d} \left[\mu_{DOF} \left\| \omega_{CSF}(\rho(L_{orig}) - \rho(\phi_b(L_{orig}, d)) \right\|_2^2 + \mu_{BD} \left\| \omega_{BD}\, \rho(\Delta_\nu(d)) \right\|_2^2 + \mu_{MP} \left\| \omega_{MP}\, \rho(\Delta_\nu(d)) \right\|_2^2 \right]$$

Depth-of-field blur | **Binocular Disparity** | **Motion Parallax**

a) Original

Perceptually-based content remapping for automultiscopic displays, SIGGRAPH 2012 (poster) [Masia et al.]

Automultiscopic displays



Perceptually-based content remapping for automultiscopic displays, SIGGRAPH 2012 (poster) [Masia et al.]

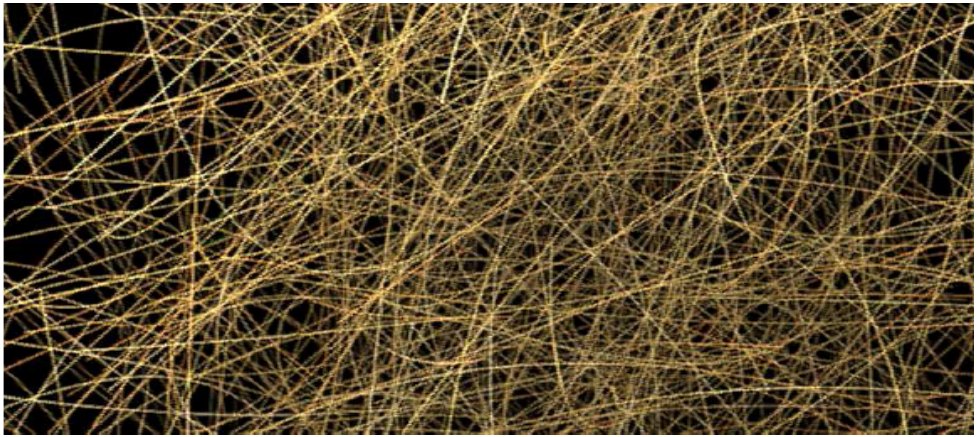
Resolution enhacement

- HVS to the rescue!

Apparent display resolution enhancement for moving images, SIGGRAPH 2010 [Didyk et al.]

Resolution enhacement

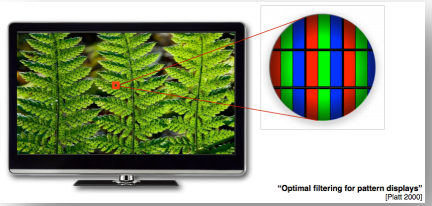
- Limited spatial resolution of displays makes showing very fine details impossible



Apparent display resolution enhancement for moving images, SIGGRAPH 2010 [Didyk et al.]

Resolution enhacement

- **Smooth pursuit eye motion**
  - Eye caught on an interesting moving feature
  - Eye tracks feature (matching velocity)
- The image will be constantly projected on predictable locations of the fovea with high density of photoreceptors
- Interesting integration effect!



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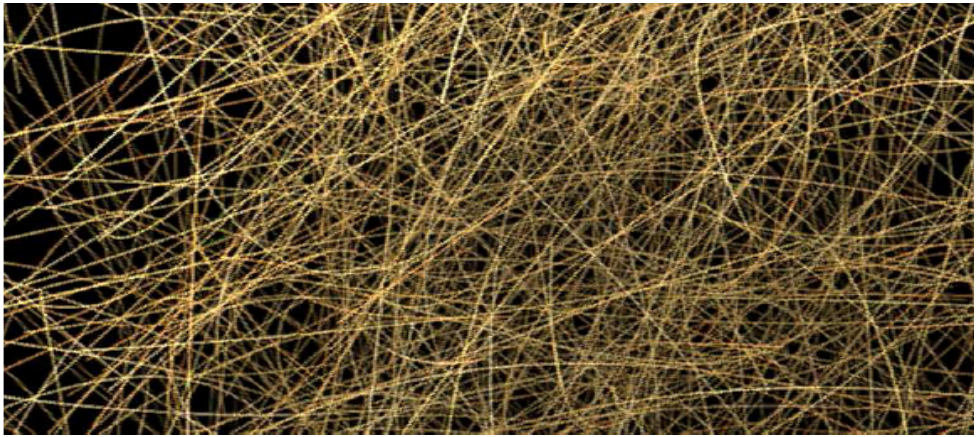

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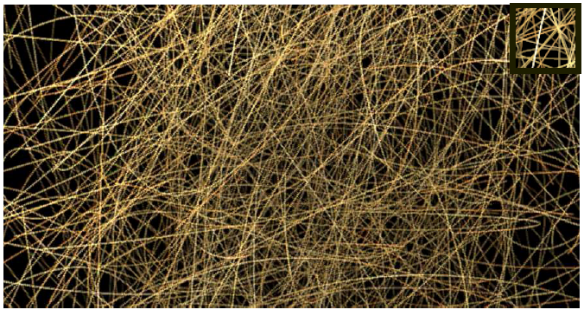
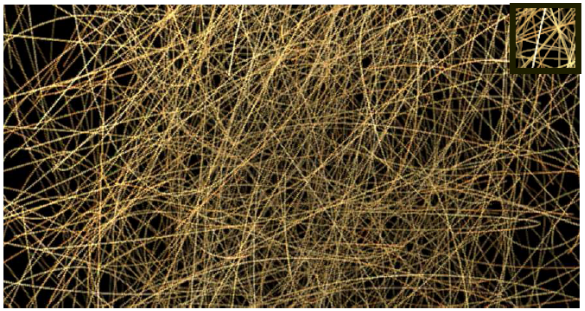


Apparent display resolution enhancement for moving images, SIGGRAPH 2010 [Didyk et al.]

Resolution enhacement



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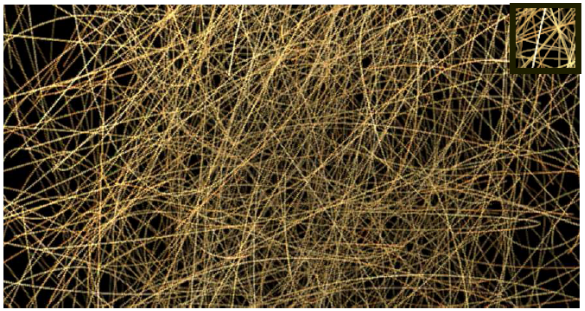

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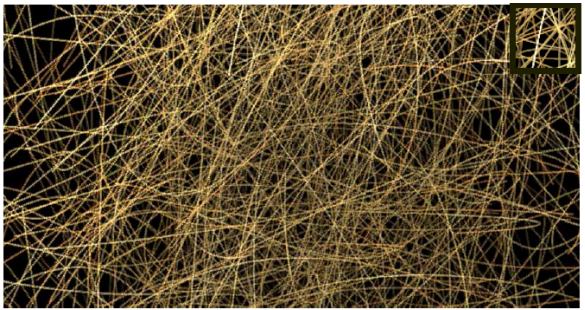

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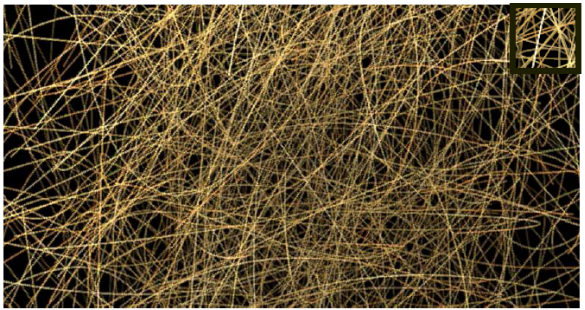

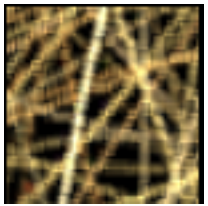

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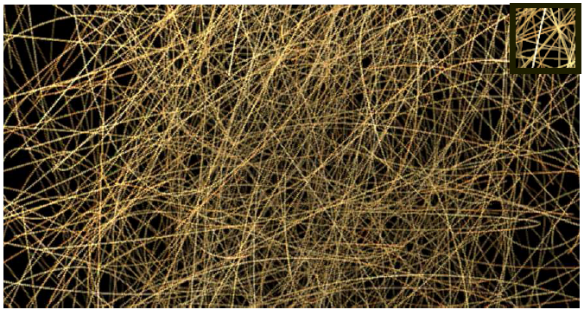

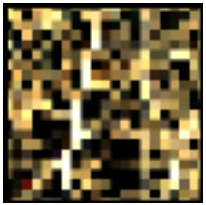

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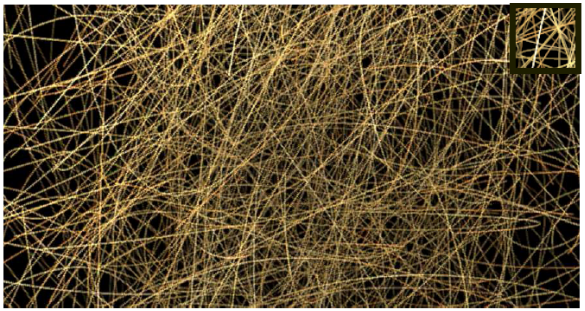

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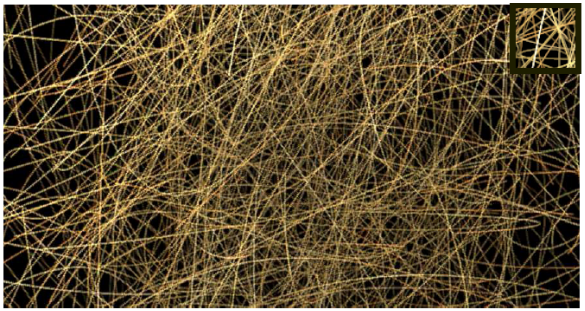

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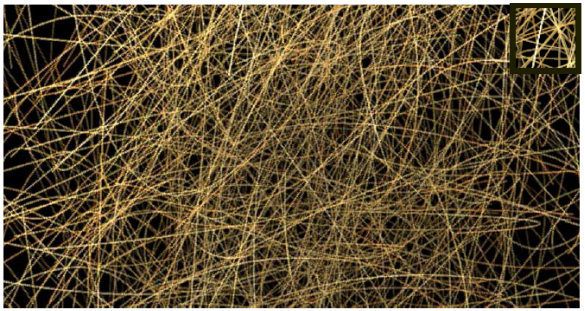
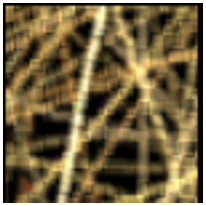
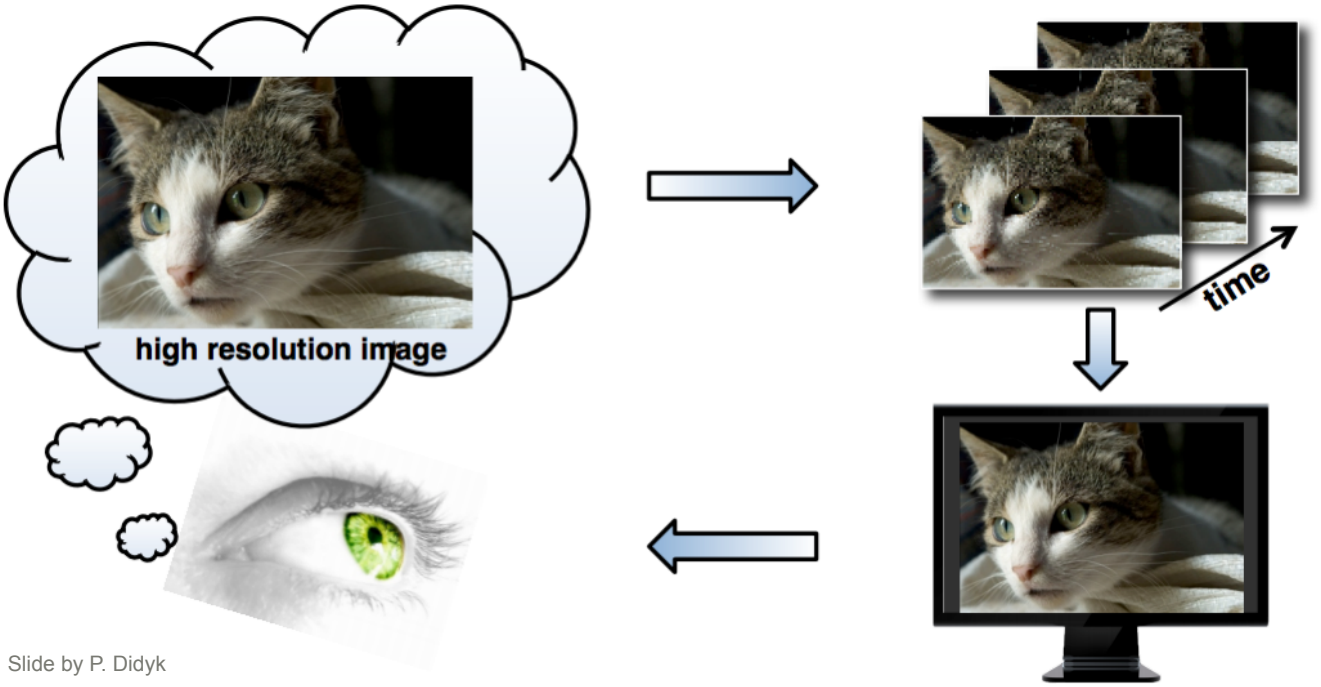




Apparent display resolution enhancement for moving images, SIGGRAPH 2010 [Didyk et al.]

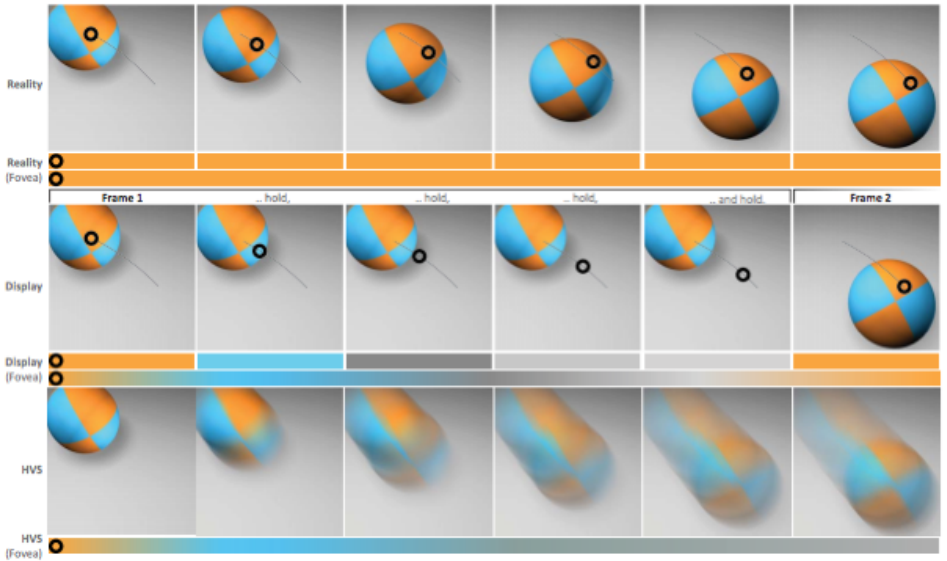
Our goal



Slide by P. Didyk

Apparent display resolution enhancement for moving images, SIGGRAPH 2010 [Didyk et al.]

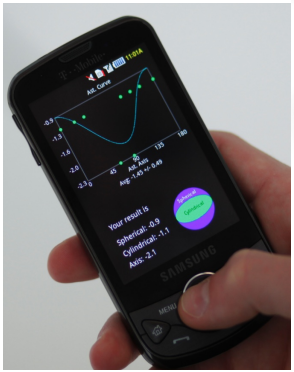
Temporal upsampling



"Perceptually-motivated real-time temporal upsampling of 3D content for high-refresh-rate displays" by Didyk et al. 2010
"Perceptual considerations for motion blur rendering" by Navarro et al. 2011

Turning things around…

- Displays that can diagnose?
  - NETRA: Near Eye Tool fro Refractive Assessment
  - CATRA: Cataract Screening Tool



EyeNetra.com

NETRA: Interactive Display for Estimating Refracting Errors and Focal Range, SIGGRAPH 2010 [Pamplona et al.]
CATRA: Interactive Measuring and Modeling of Cataracts, SIGGRAPH 2011 [Pamplona et al.]

Conclusions

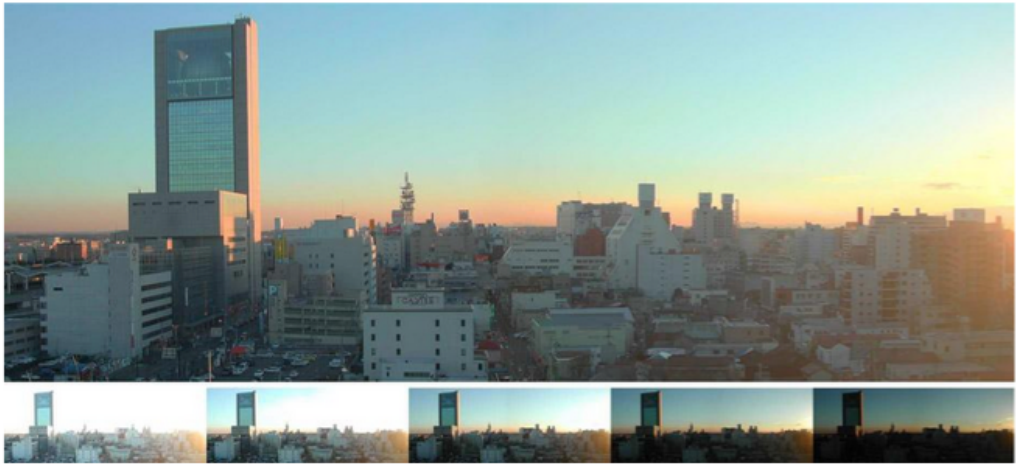
- **The HVs can play an important role in designing future displays**

- The list of examples is very extensive
  - Only a small set of examples shown here
- Some fields have seen a lot of action already (tone mapping, color…)
- Others are hot today (stereo…)
- Others are quite revolutionary

Perceptual Digital Imaging: Methods and Applications

Piotr Didyk, Tobias Ritschel, Elmar Eisemann, Karol Myszkowski
Exceeding Physical Limitations: Apparent Display Qualities

CRC Press



Conclusions

- So what awaits for us in the future?

- Vibrating displays will further exploit the temporal integration in the retina
- Future displays will free the viewer from needing optical corrections (glasses)
  - A light field will be split into multiple instances focused at different distances

Conclusions

- So when will this occur?

Conclusions

- So when will this occur?

This Wednesday

Conclusions

- So when will this occur?

This Wednesday

Technical Papers Session: **Displays**

Wednesday, 8 August, 0900-1030

Room 408A

Thanks for your attention

For the latest version of the slides, please go to:

http://giga.cps.unizar.es/~diegog/pub.html