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# Stereoscopic 3-D video for the human eyes

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research done within the 3DLive project

with
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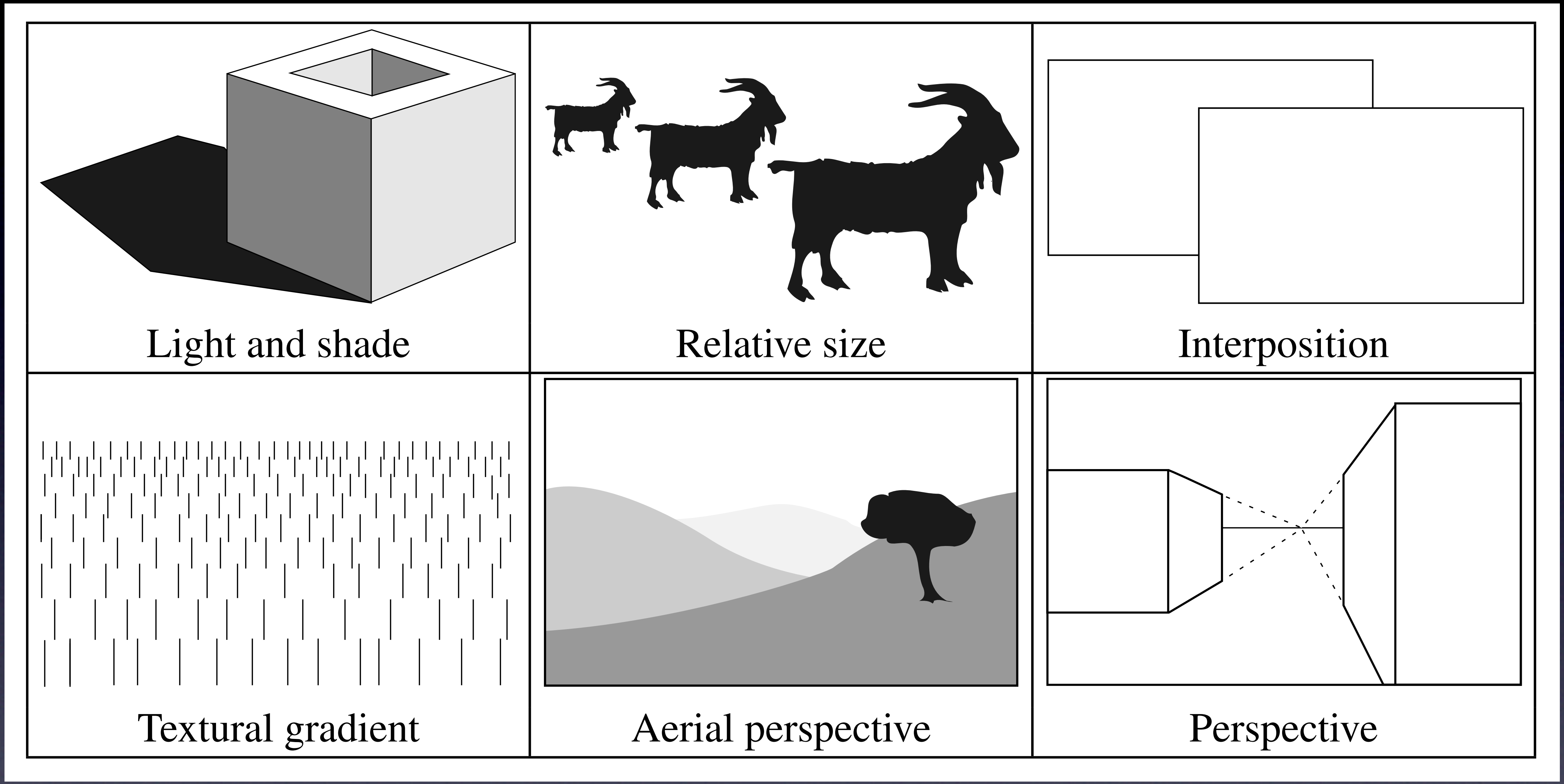
*Images 3D : acquisition, synthèse et visualisation*
*October 14, 2010*

# Three-Dimensional Depth Cues

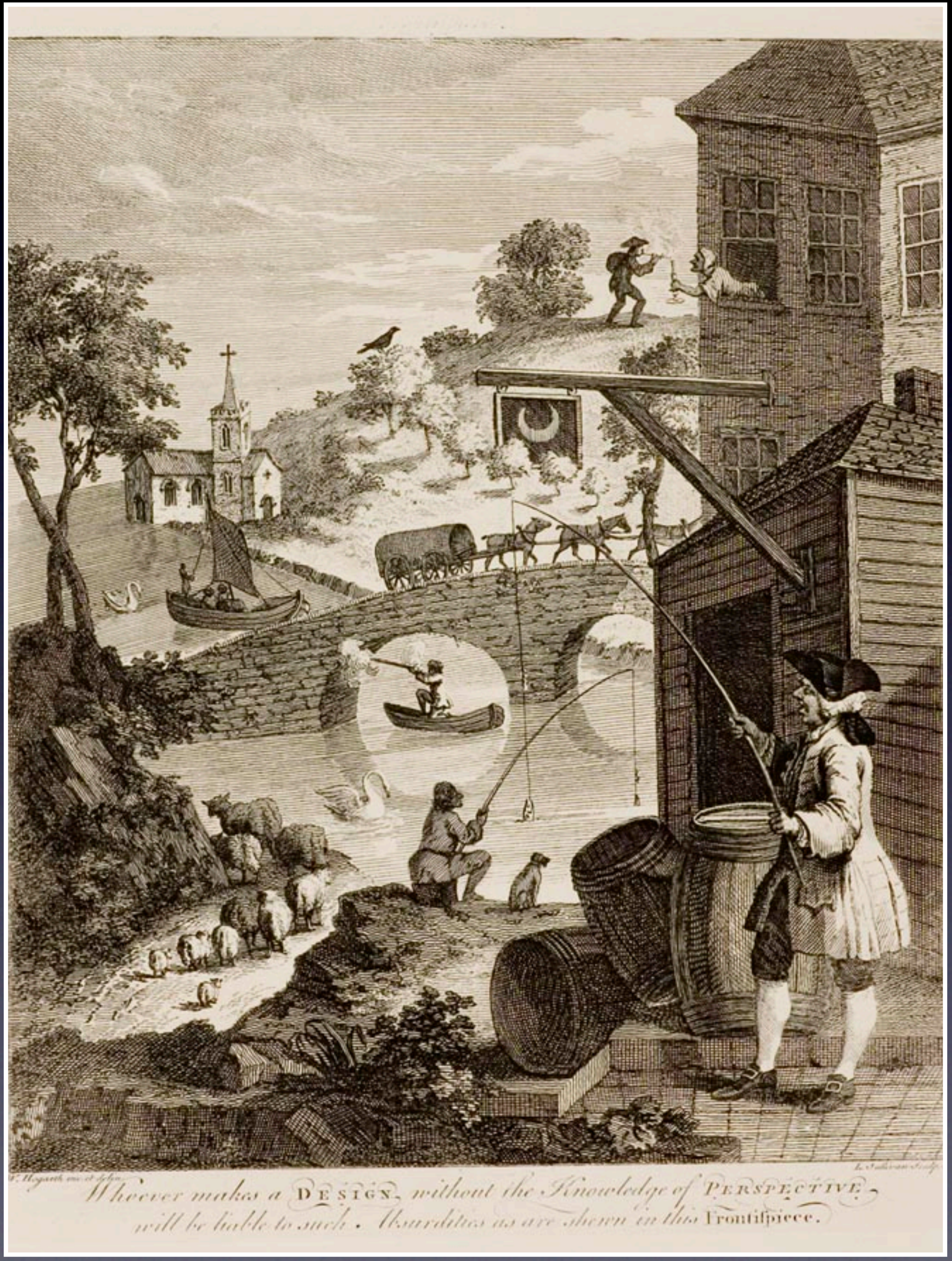



And also **motion parallax**, **depth of field**, and... **stereoscopy**

Depth of field as a depth cue: focus matters!

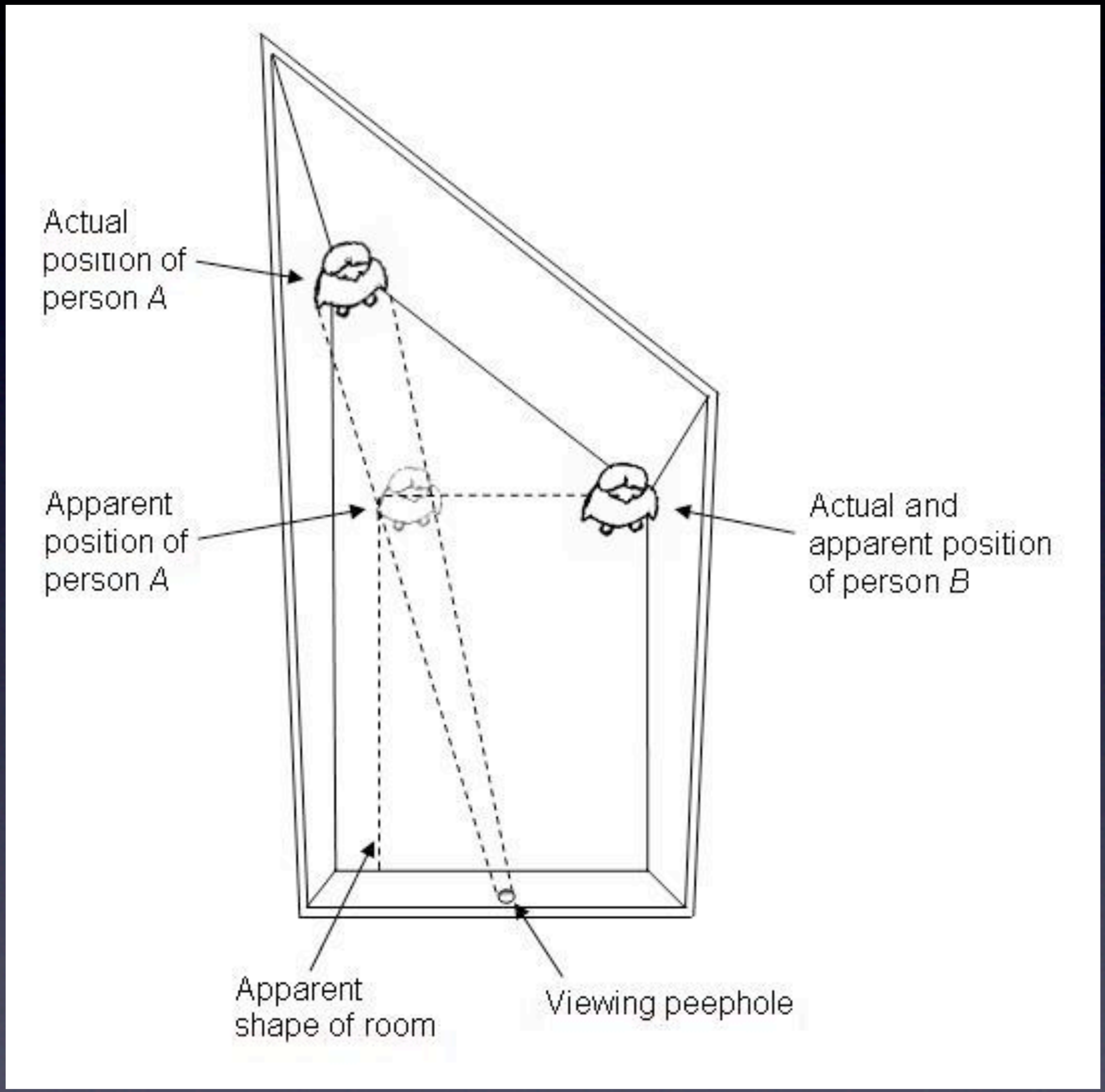
# Conflicting depth cues

- The 9 cues may give opposite indications on the scene geometry
- The **pseudoscope** (Wheatstone) - reverse left and right eyes - causes *closer* objects to seem even *bigger*:
  - big in the image
  - binocular disparity indicates they are also far away




William Hogarth, 1754

# Conflicting cues: Ames room




Used in *Lord of the Rings*,
*Eternal Sunshine of the Spotless Mind*...

# Stereoscopic conflicting cues: Coraline 3D

Coraline (H. Selick & P. Kozachik)

2 vanishing points in the same 3-D scene



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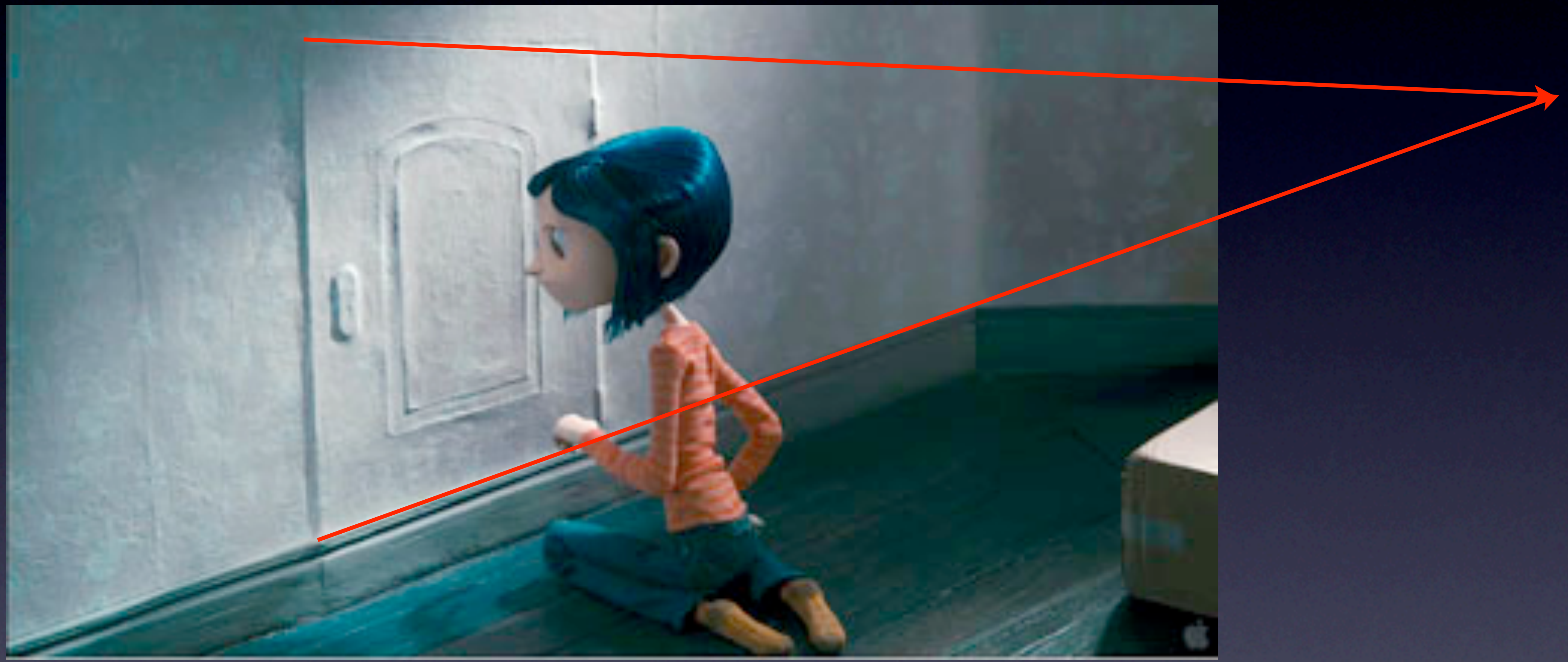

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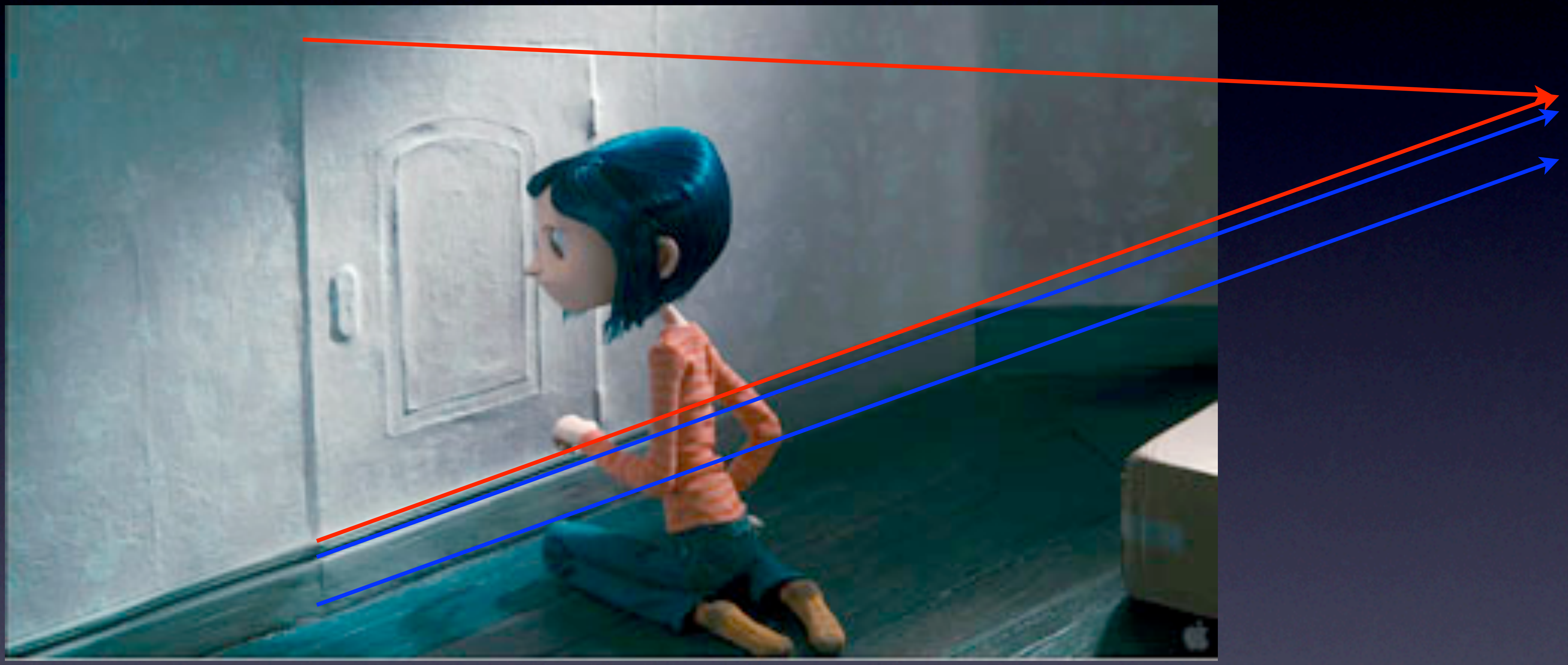

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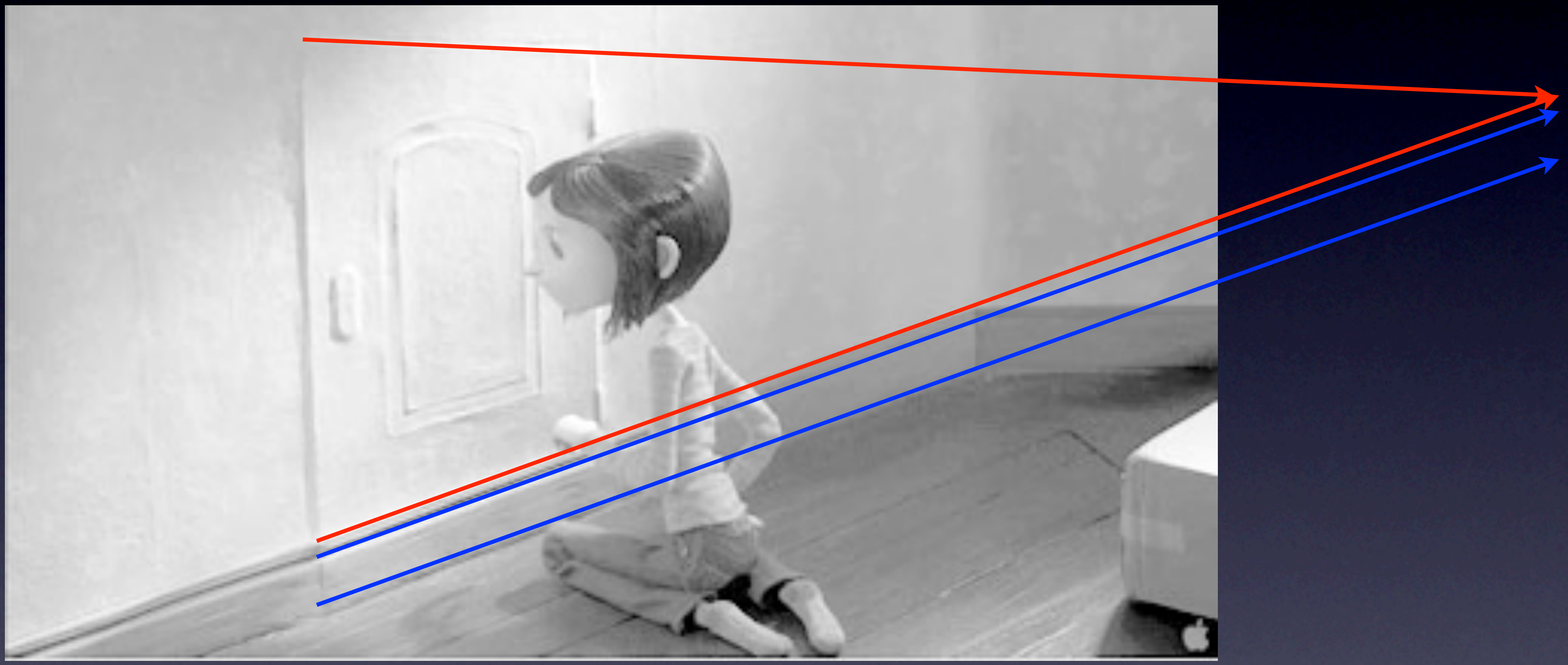

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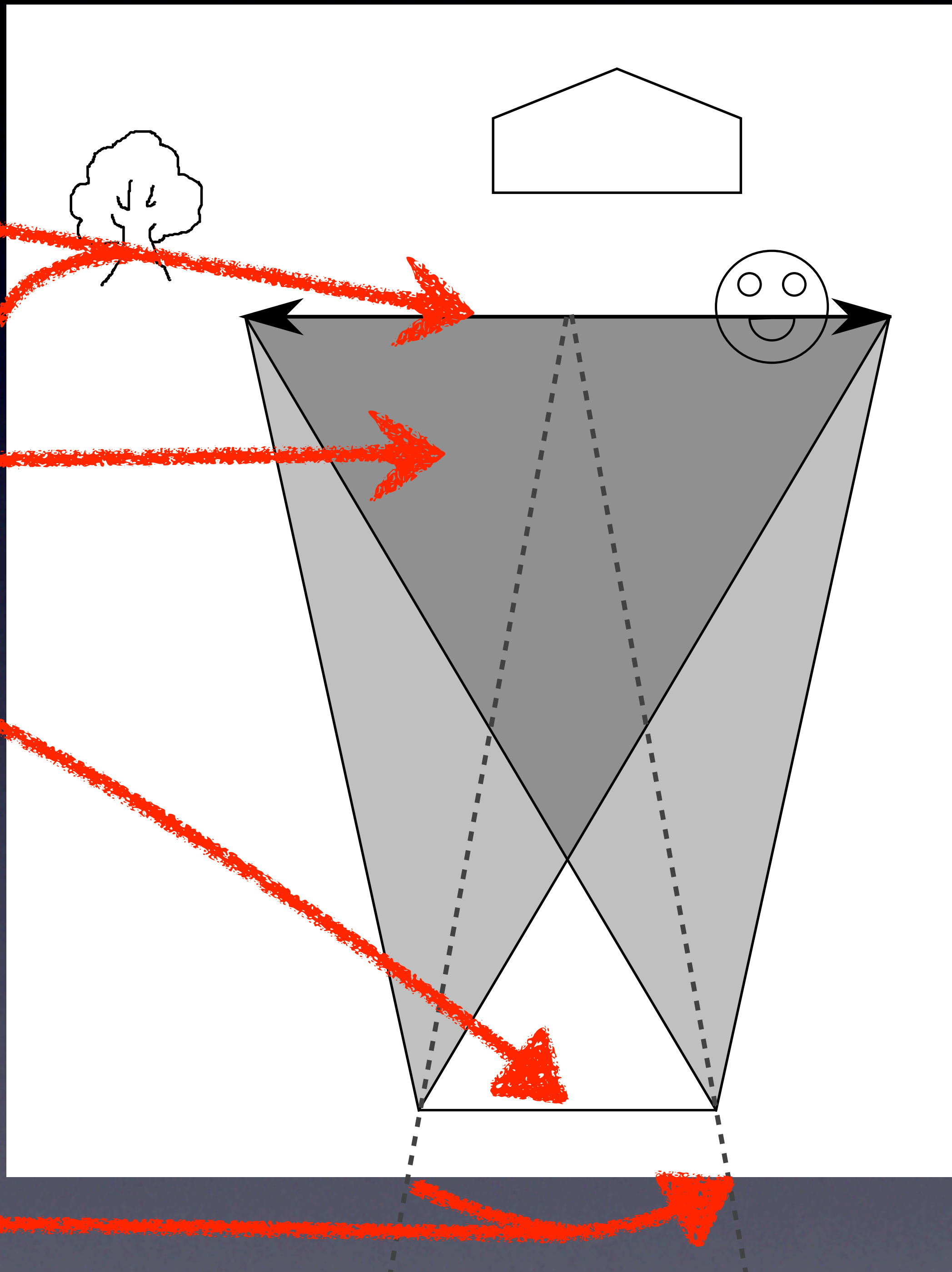
- Playing with the depth of focus
- Playing with the proscenium
- 3-D compositing (real or CG scenes)

# A few definitions

- Two cameras, two eyes
- Screen plane ... in the viewer space
- Plane of convergence .. in the scene space
- 3-D cone
- Interocular / Interaxial
  - bigger than 65mm (can be 30m)$\Longrightarrow$ hyperstereo (or miniaturization)
  - smaller than 65mm (can be 0cm) $\Longrightarrow$ hypostereo (or gigantism)
- Convergence





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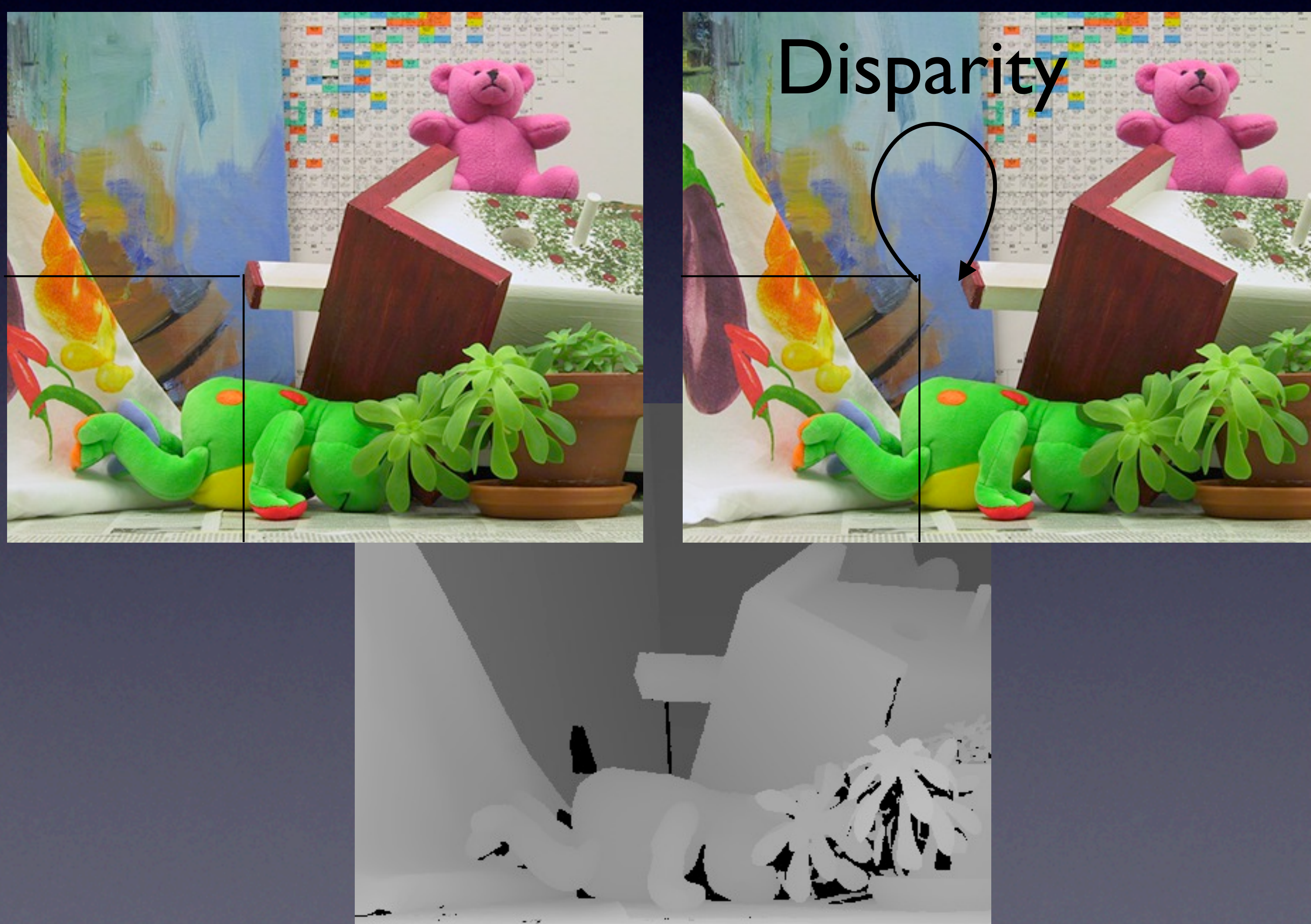
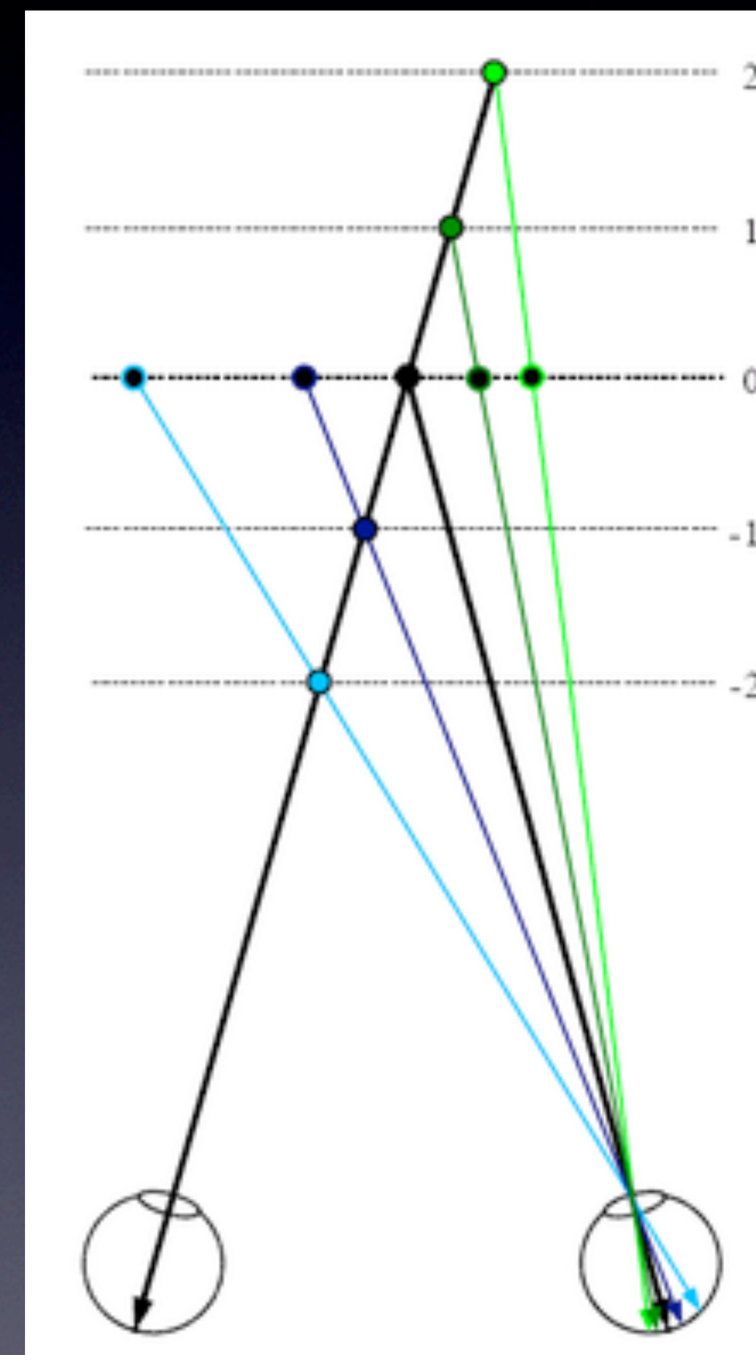
# Binocular disparity: why we see in 3D

- Objects at different depths cause different disparities



# left view



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# right view



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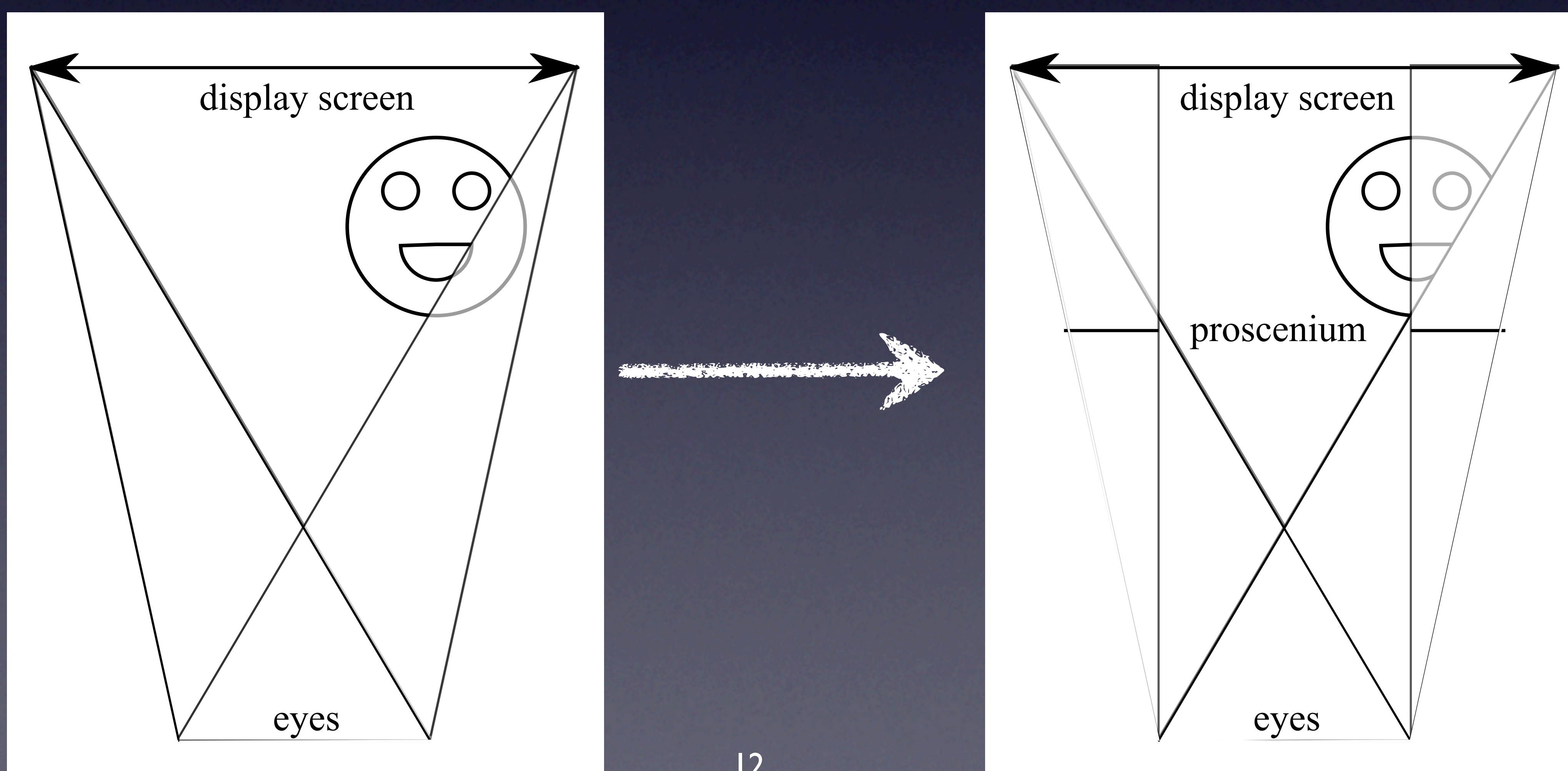
# The proscenium arch (or stereoscopic window)

**The screen is a window on the world**

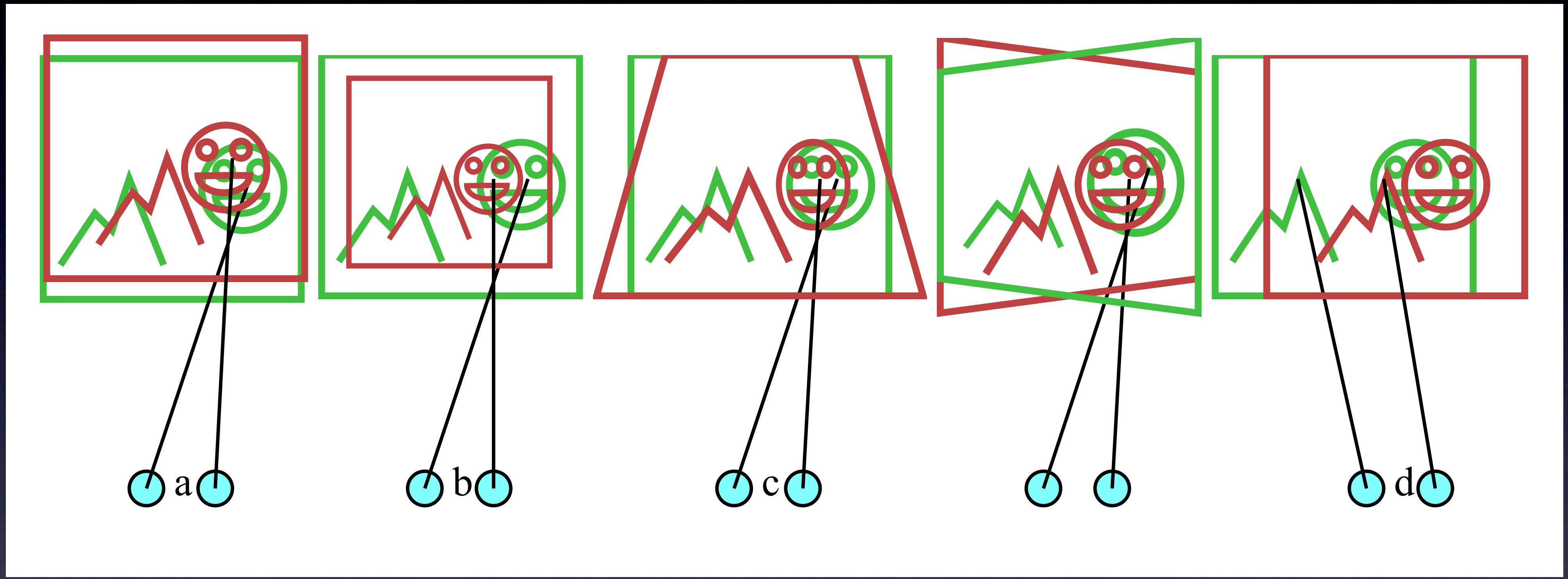
If object closer than convergence plane touches the image borders...
$\Longrightarrow$ Add black borders to move proscenium arch closer



# Visual fatigue (1) a critical point

- Can lead to:
  - a simple headache
  - temporary or permanent damage to the oculo-motor system (especially on children)
- **A public health problem** (just as the critical fusion frequency on CRT screens...)

# Visual fatigue (2) geometric differences




a. vertical shift
b. size difference
c. distortion difference
d. keystone (toed-in cameras)
e. horizontal shift (divergence...)



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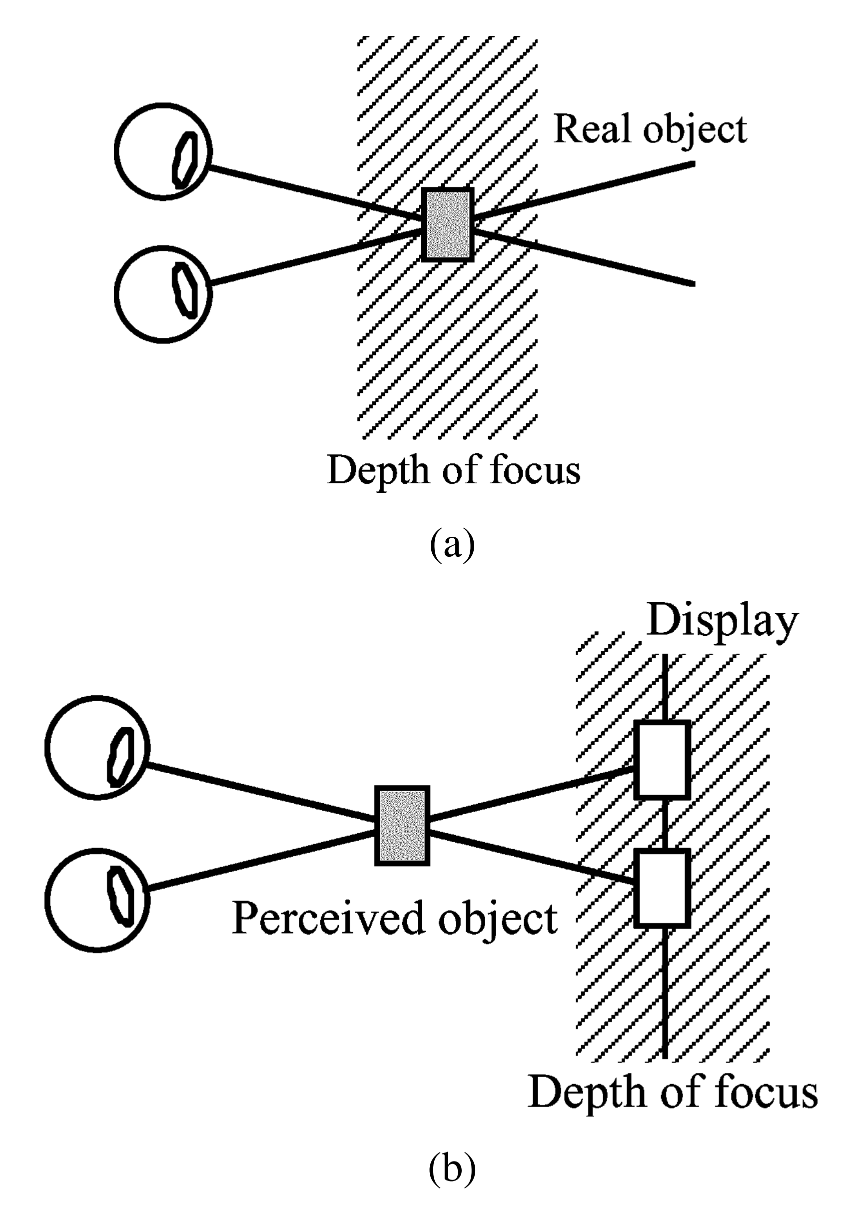
# Visual fatigue (3)
## accommodation and convergence discrepancy

distance of accommodation
= distance to screen
≠ distance of convergence

Different display
⇒ Different depth of field:

- 3DTV (3.5m): 2m → 12m
- Movie theater (16m): 4m → infinity



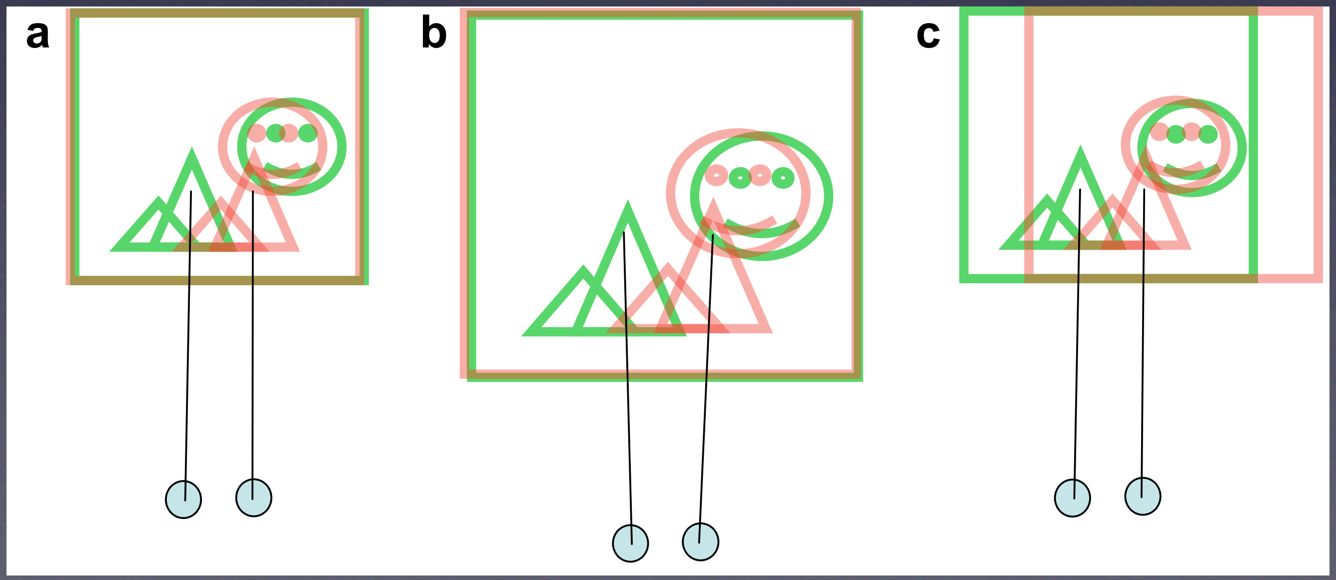

Emoto *et al.* 2005

# Visual fatigue (4) screen size

One 3-D movie, different screens $\Longrightarrow$ risk of divergence

Shifting the images solves divergence problems, but creates other problems:

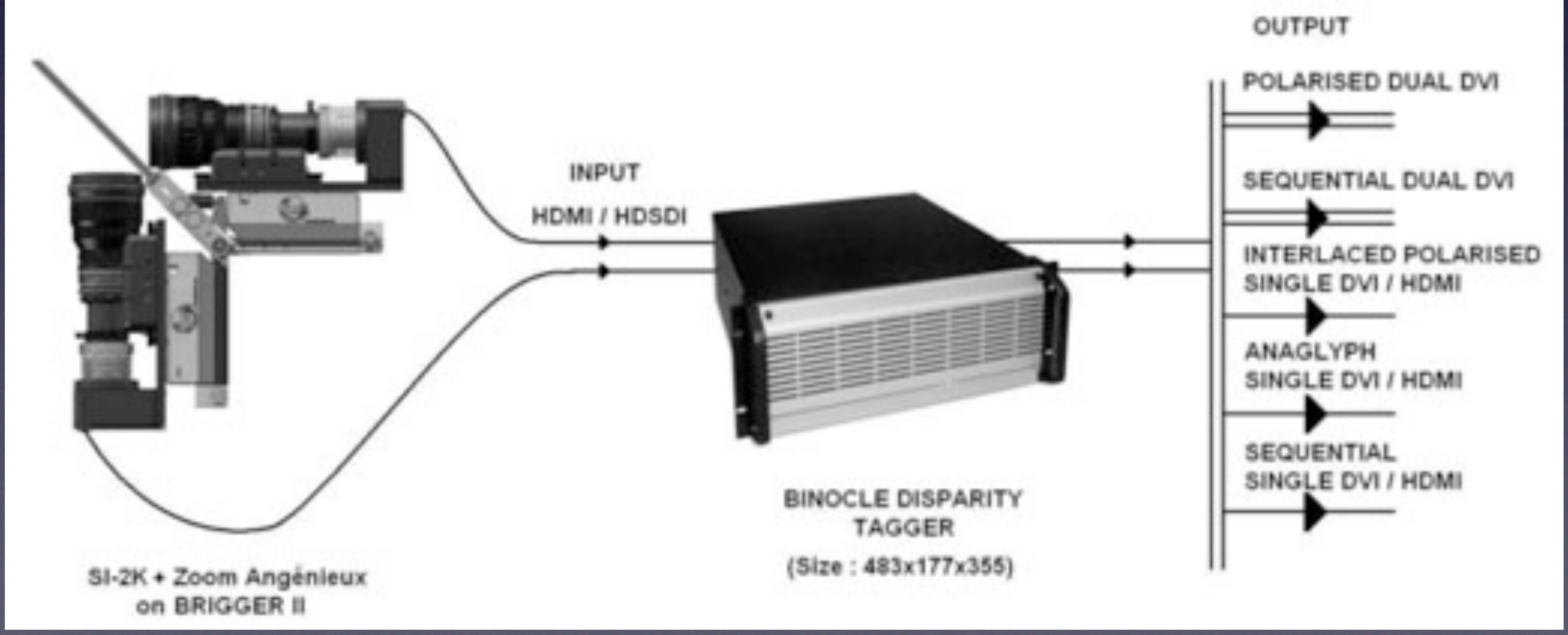
- Breaks the stereoscopic window
- Causes depth distortions




Ukai & Howarth 2008

# Correcting geometric differences: the problem

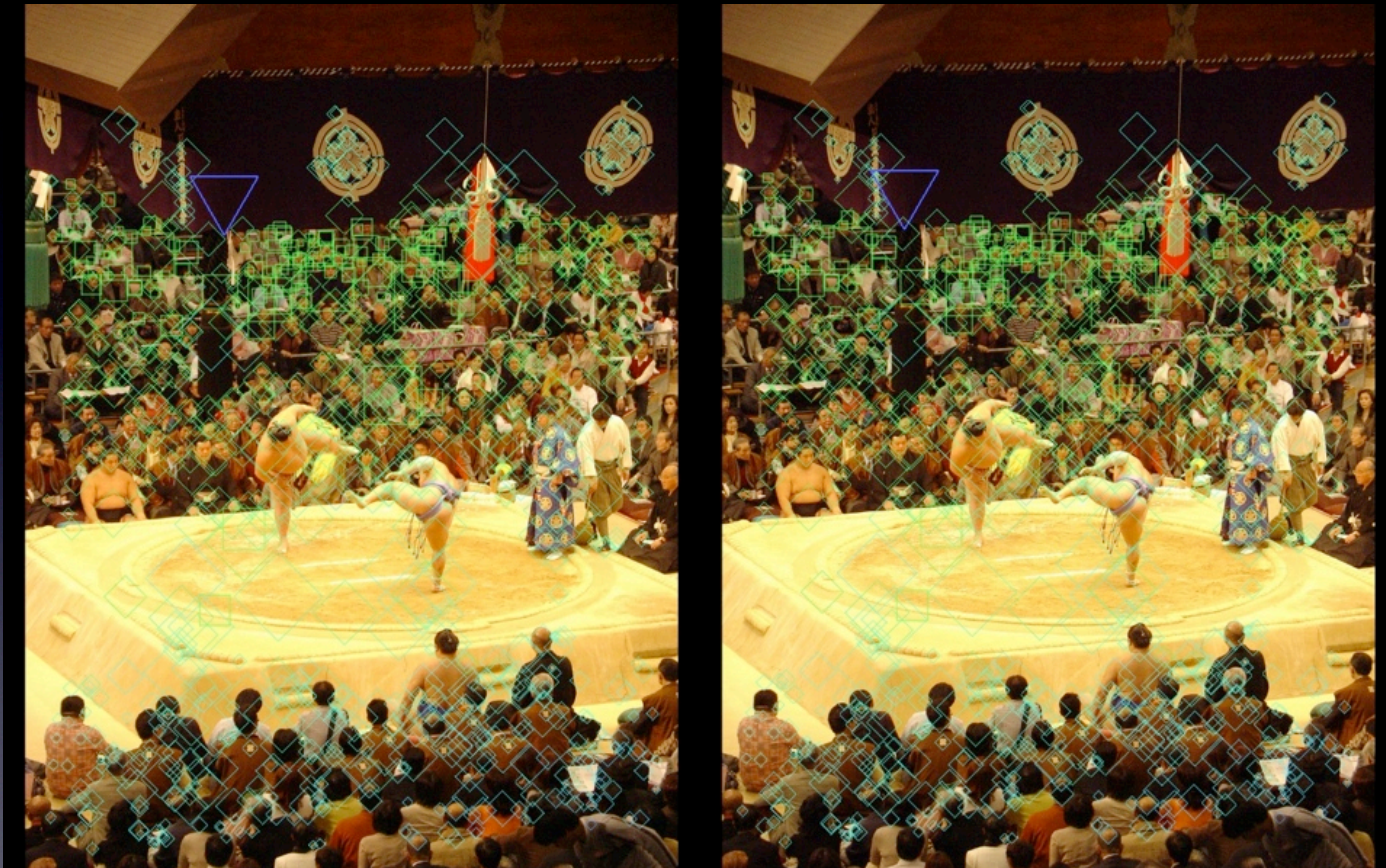
- Mechanics and optics are intrinsically imprecise
- Check that the 3D movie can be comfortably viewed on a given screen (movie theater or 3DTV)
- On output, disparity must be purely horizontal
- **Transform the images to remove geometric differences**



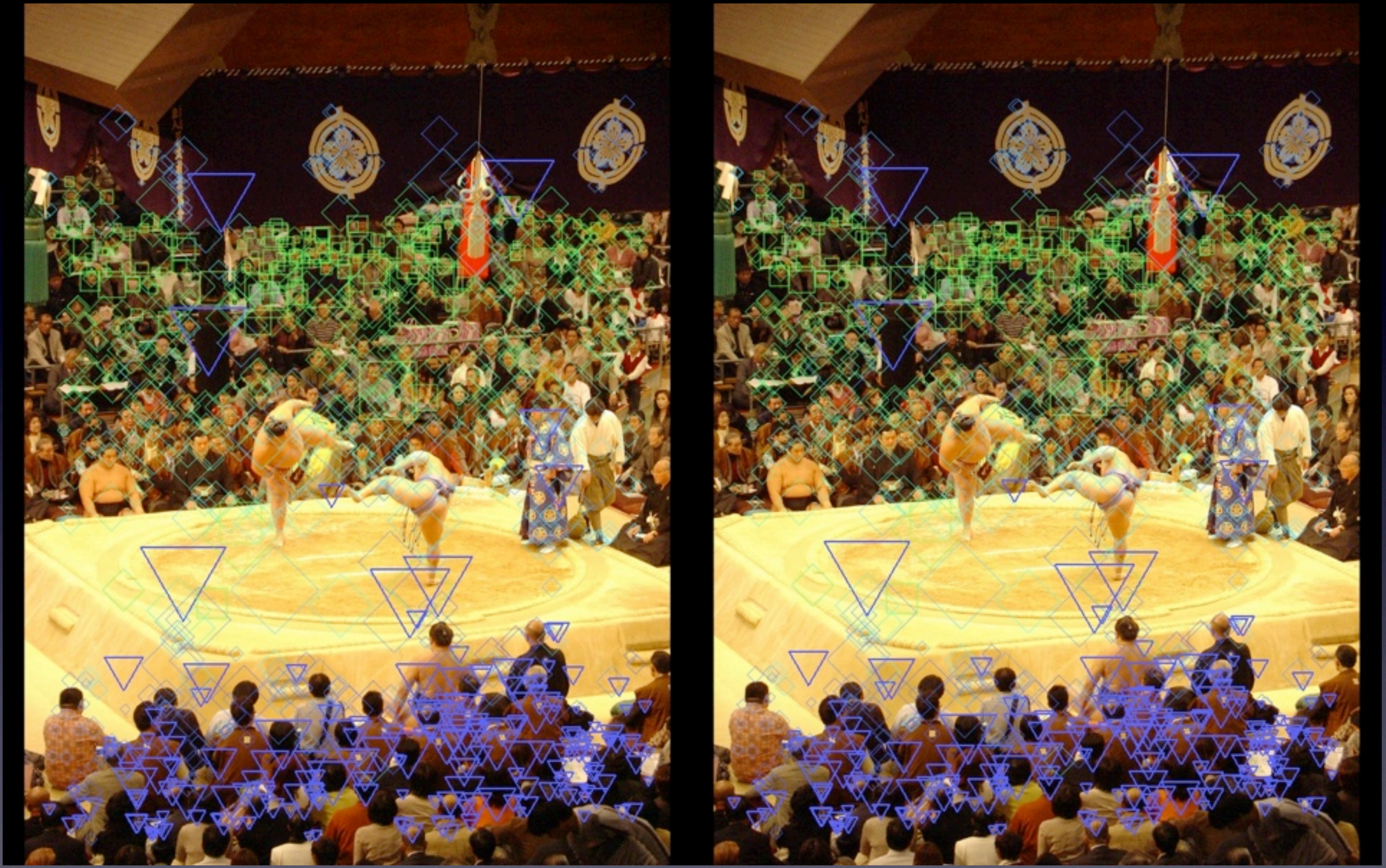
# DisparityTakker: The Binocle / INRIA solution

- Detect remarkable points or regions in both images
- Match these points and regions
- Compute image transformations to remove vertical disparities
- Real-time correction of HD-SDI stereoscopic streams (2 x 1080p60)



Alerts for a 4m wide screen



Alerts for a 10m wide screen: crowd too close!



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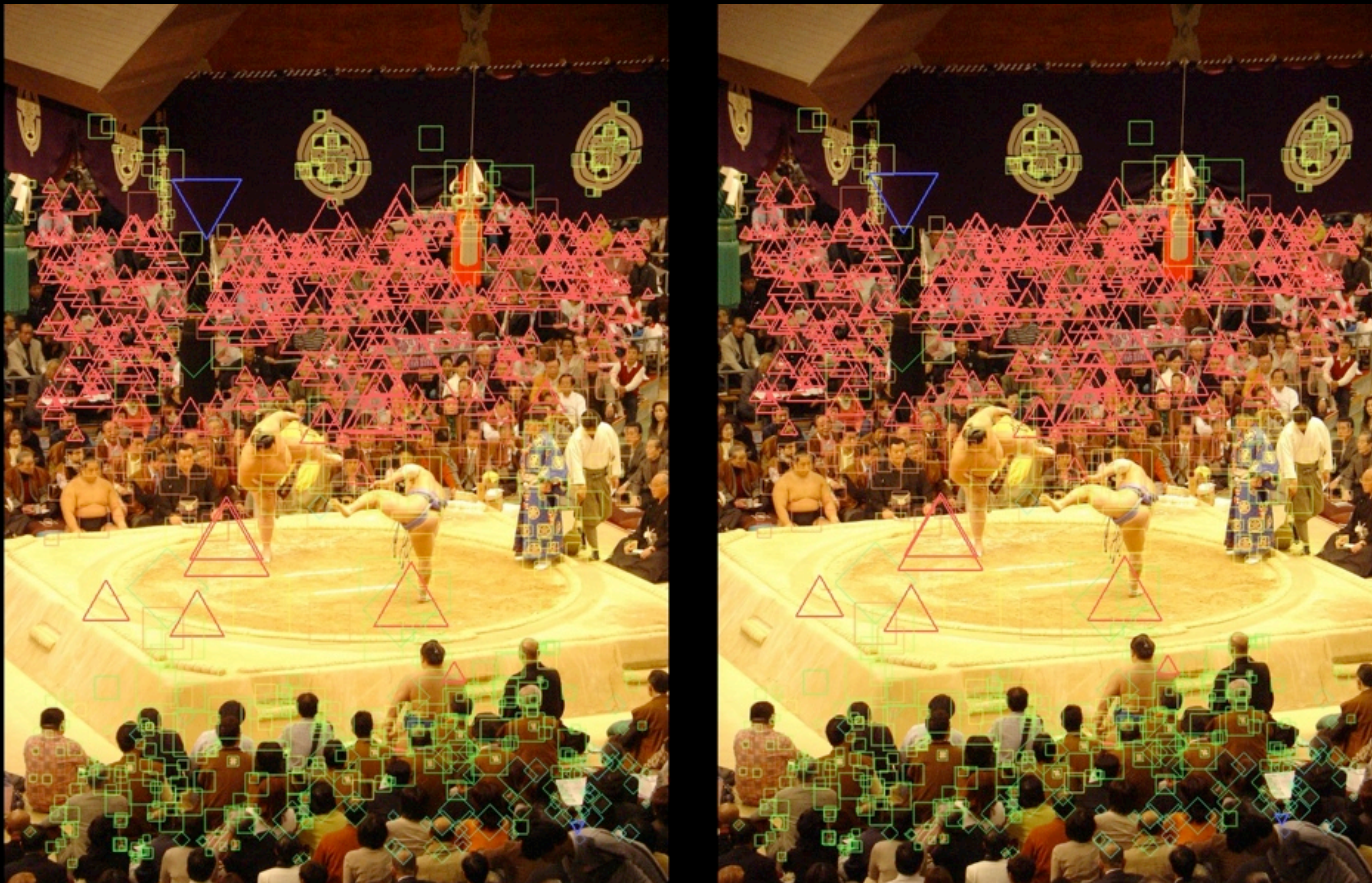

Alerts for a 10m wide screen + shift: divergence!



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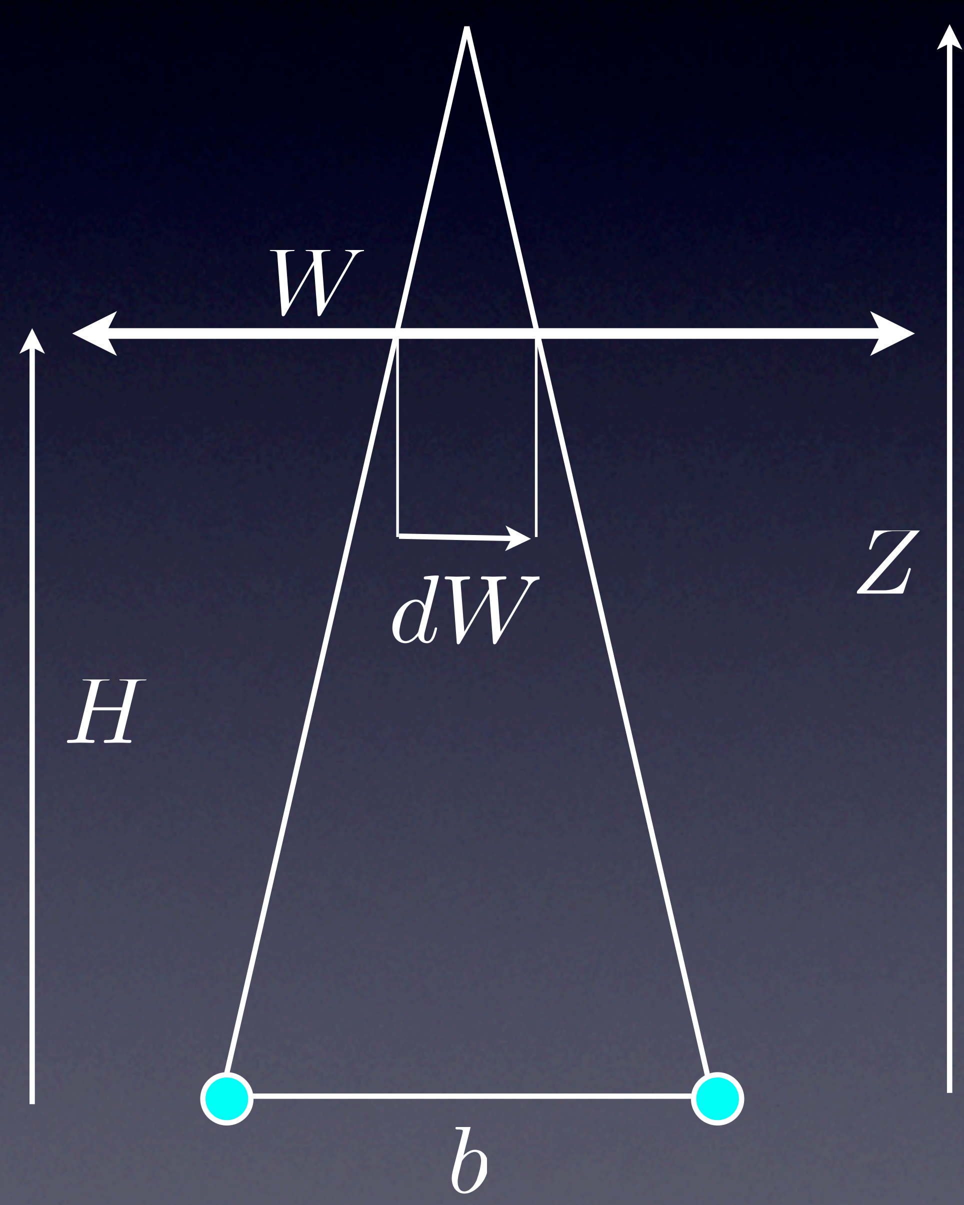
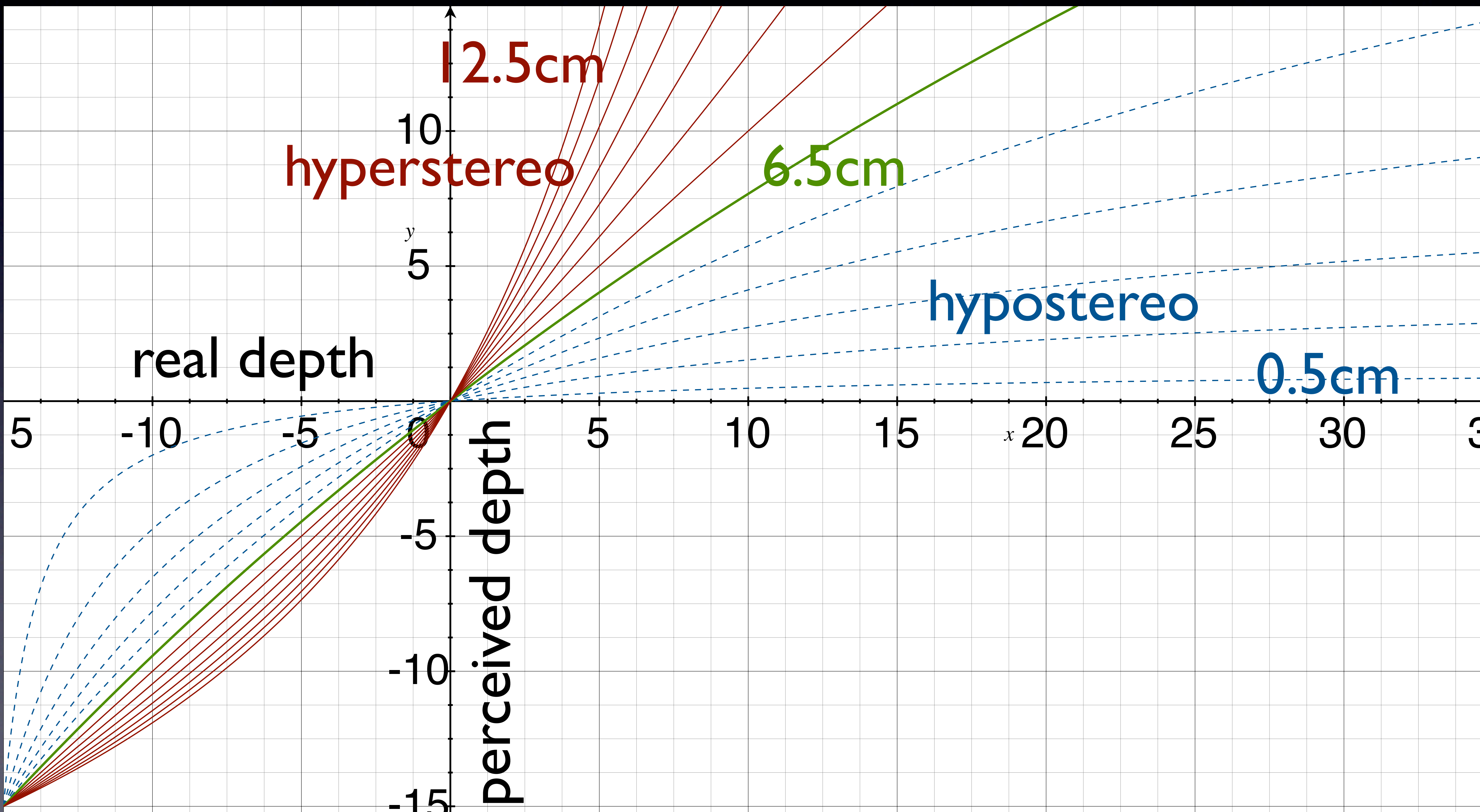
# Global depth modifications: adapting to the display

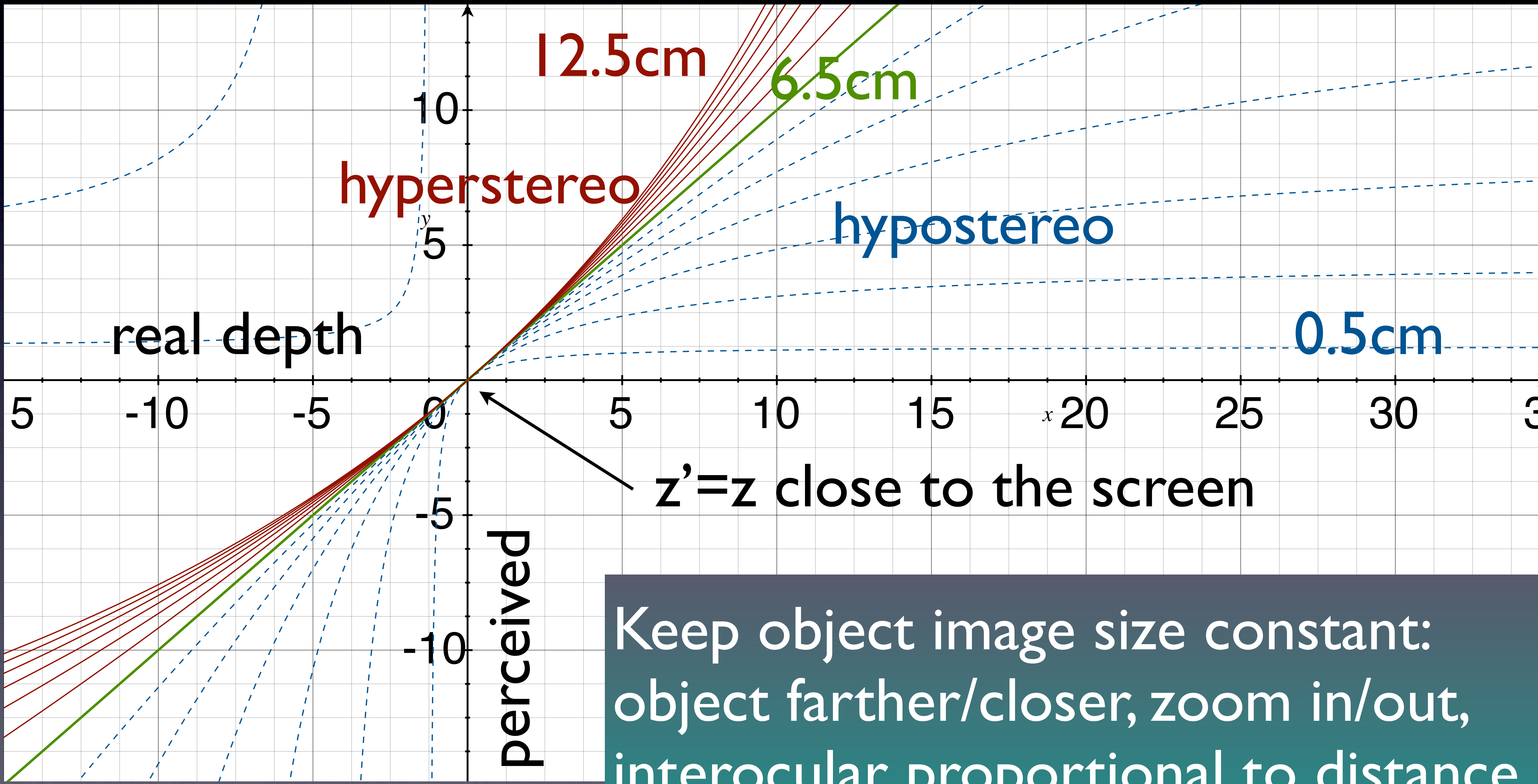
| | camera | display |
|---|---|---|
| b | camera interocular | eye interocular |
| H | convergence distance | screen distance |
| W | width of convergence plane | screen size |
| Z | real depth | perceived depth |
| d | disparity (as a fraction of W) | |



# Global depth modifications: changing b (camera interocular)



# Global depth modifications:
# $H = \alpha b$

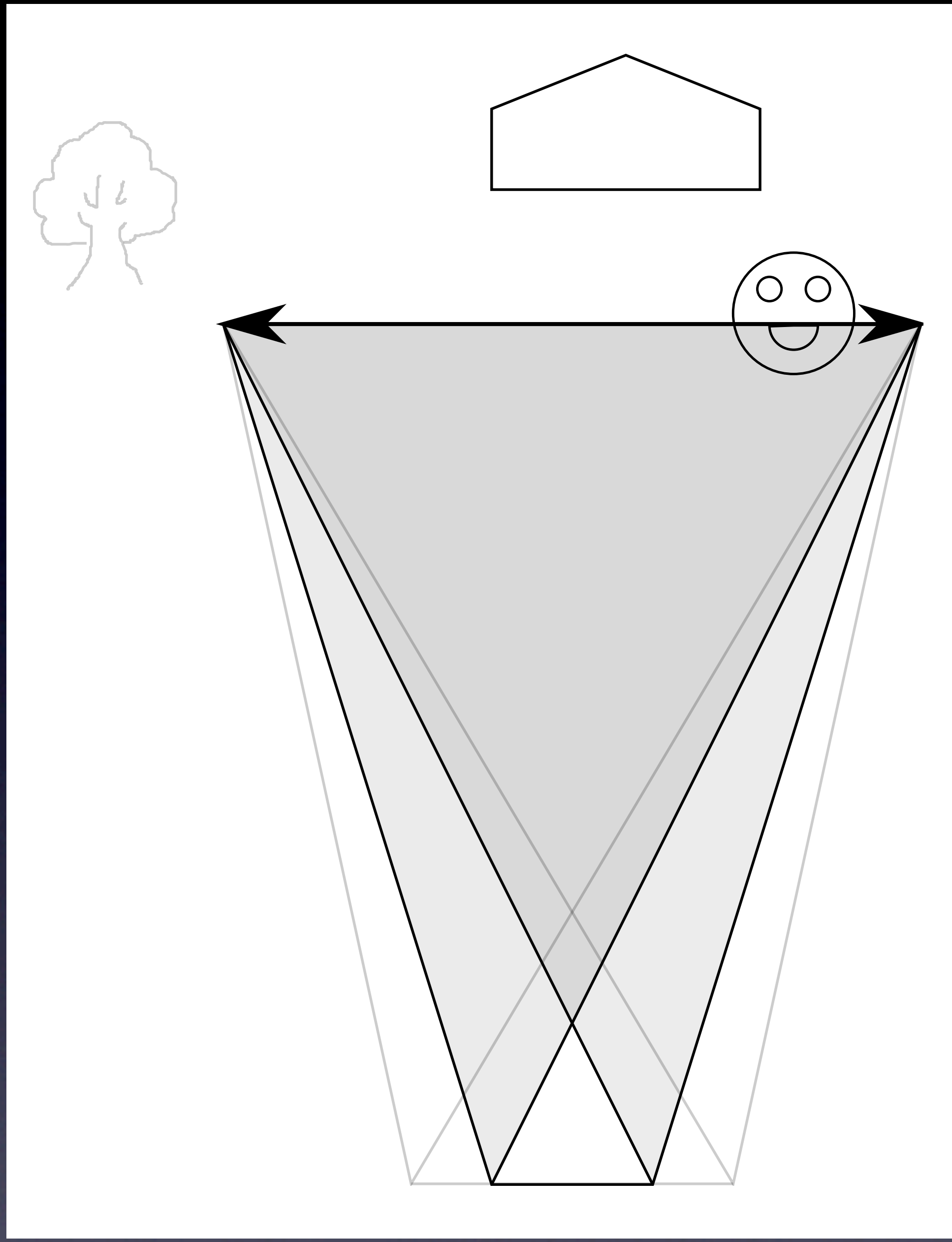



Keep object image size constant: object farther/closer, zoom in/out, interocular proportional to distance

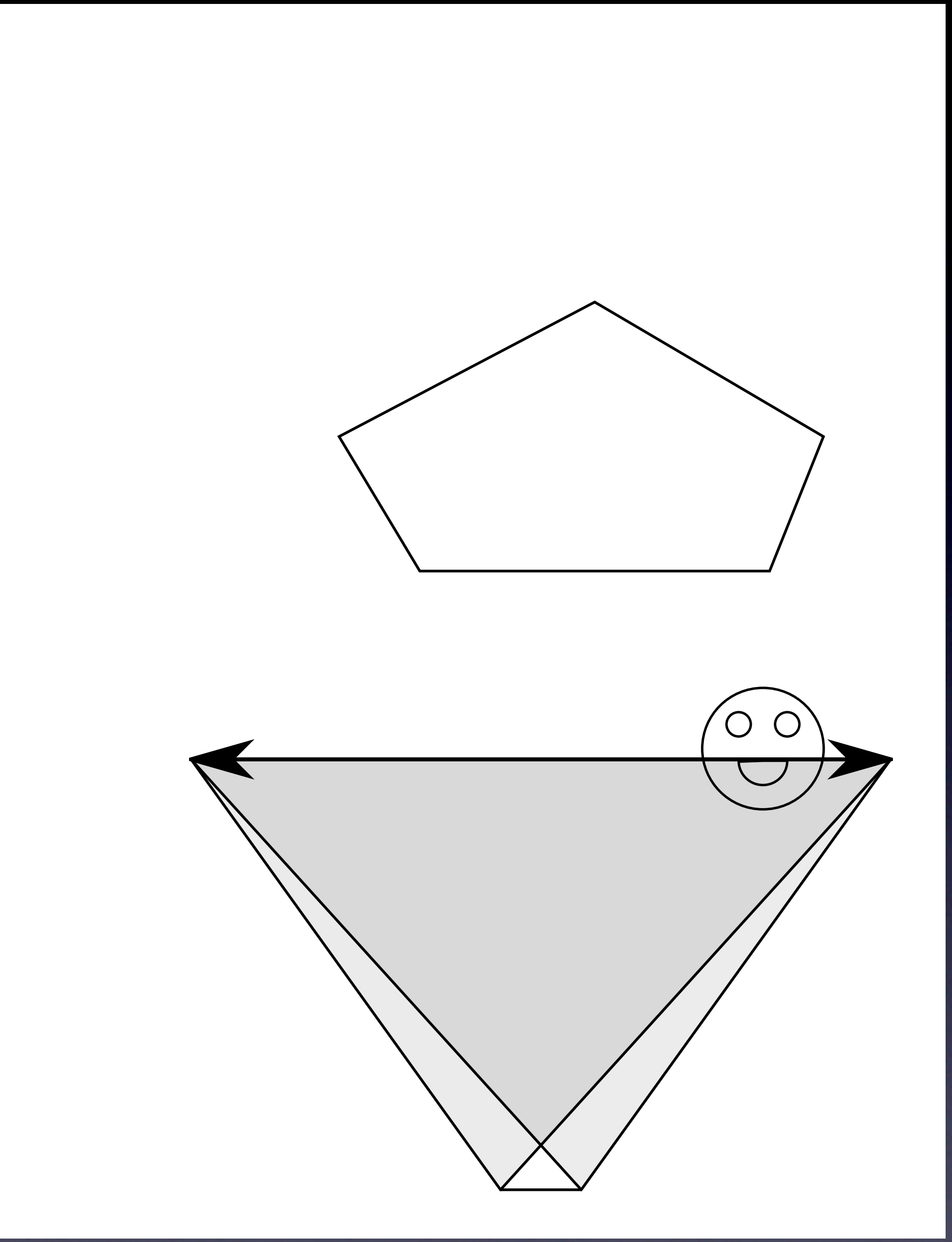
# Perceived depth distortions

- 3D geometry is not distorted if and only if shooting and viewing geometry are the same
  - used for IMAX-3D
  - impossible in real situations (sports...)
  - may break the stereoscopic window
- Objects don’t look «more 3D» on a bigger screen
- Distance is important: «more 3D» if screen farther
- **New view synthesis** is the only solution (requires depth map)

# New view synthesis: baseline modification



Scene geometry



Viewing geometry

Objects on screen are not distorted, but everything else is **very** distorted! **Divergence** may happen!



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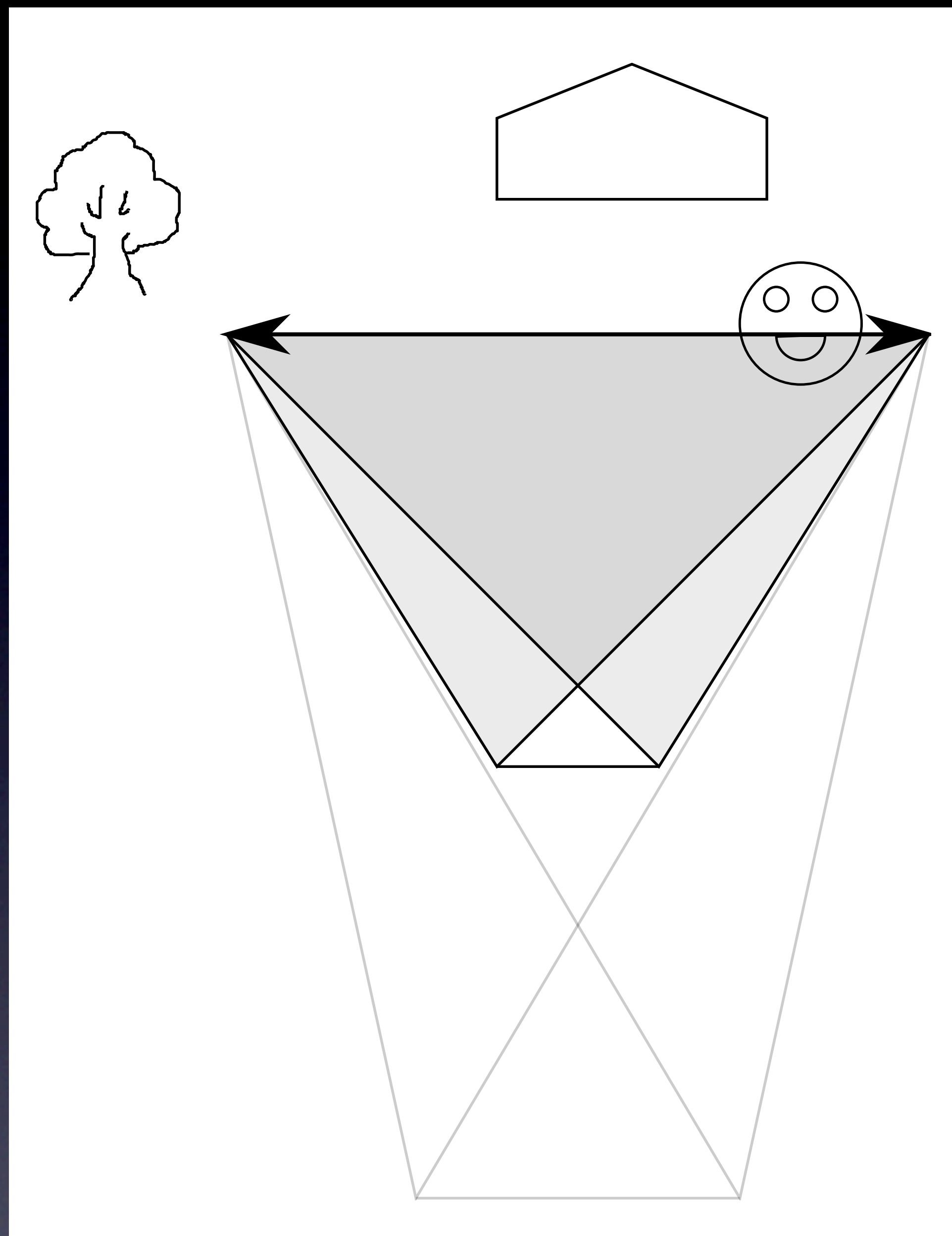
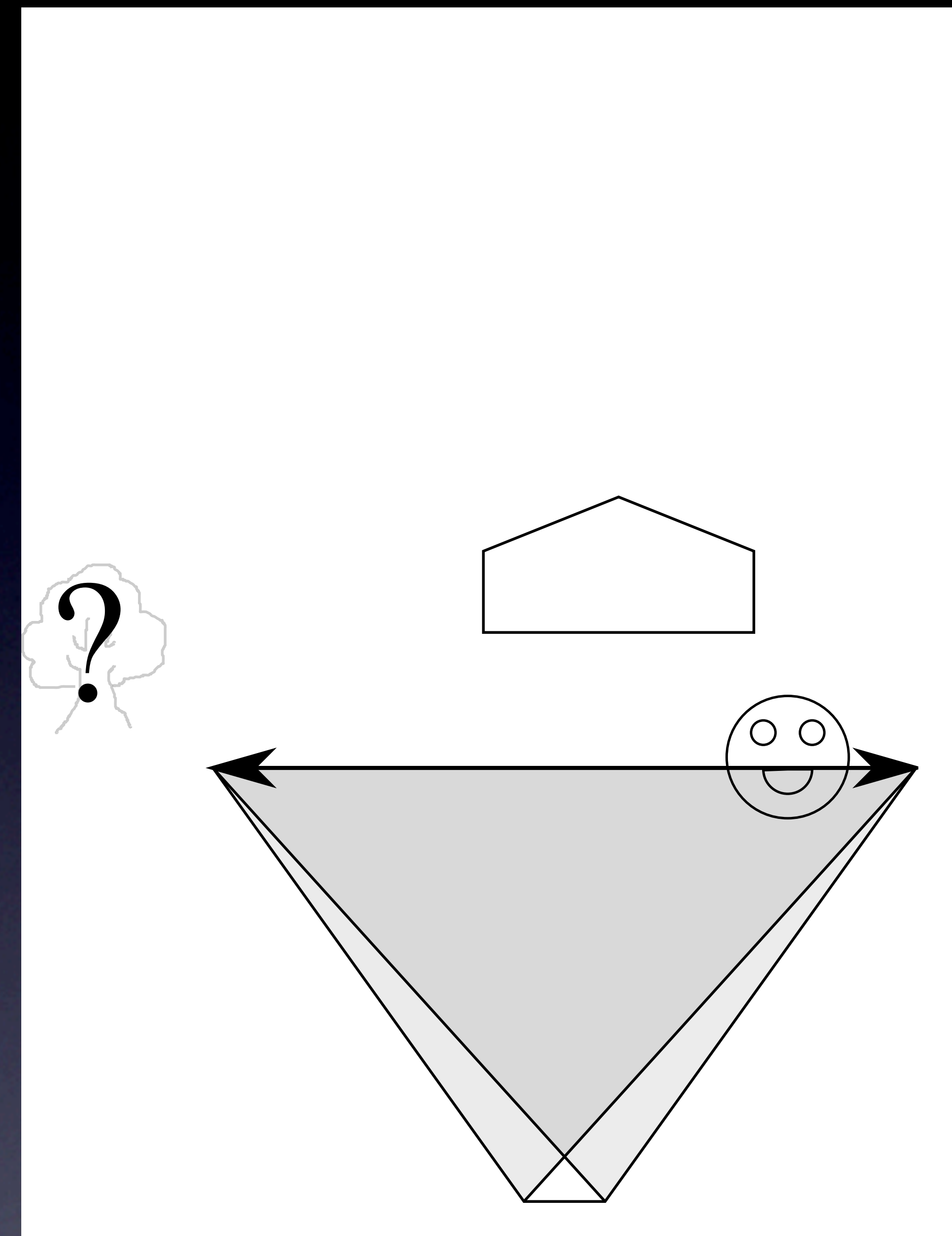
# New view synthesis: viewpoint modification



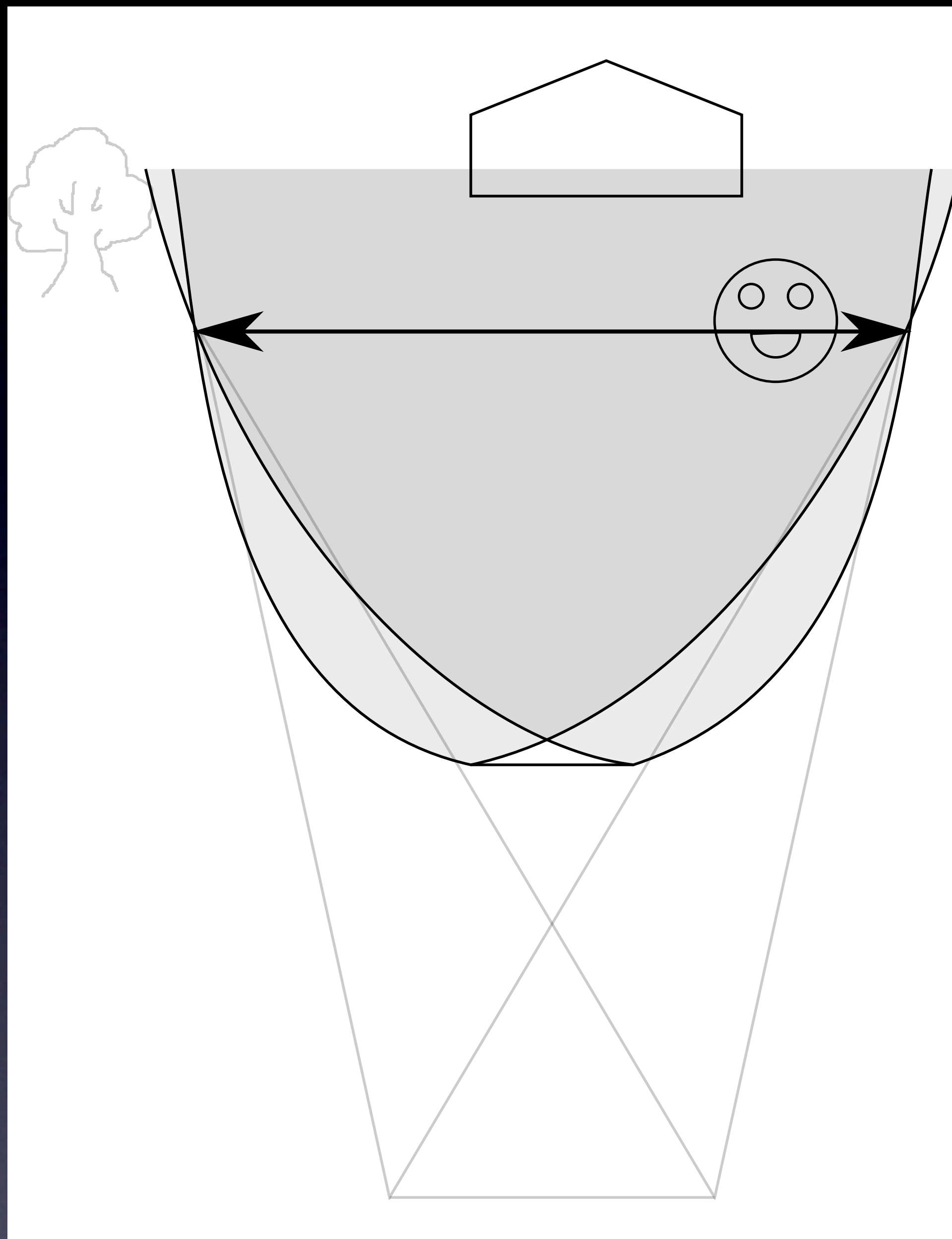
Scene geometry



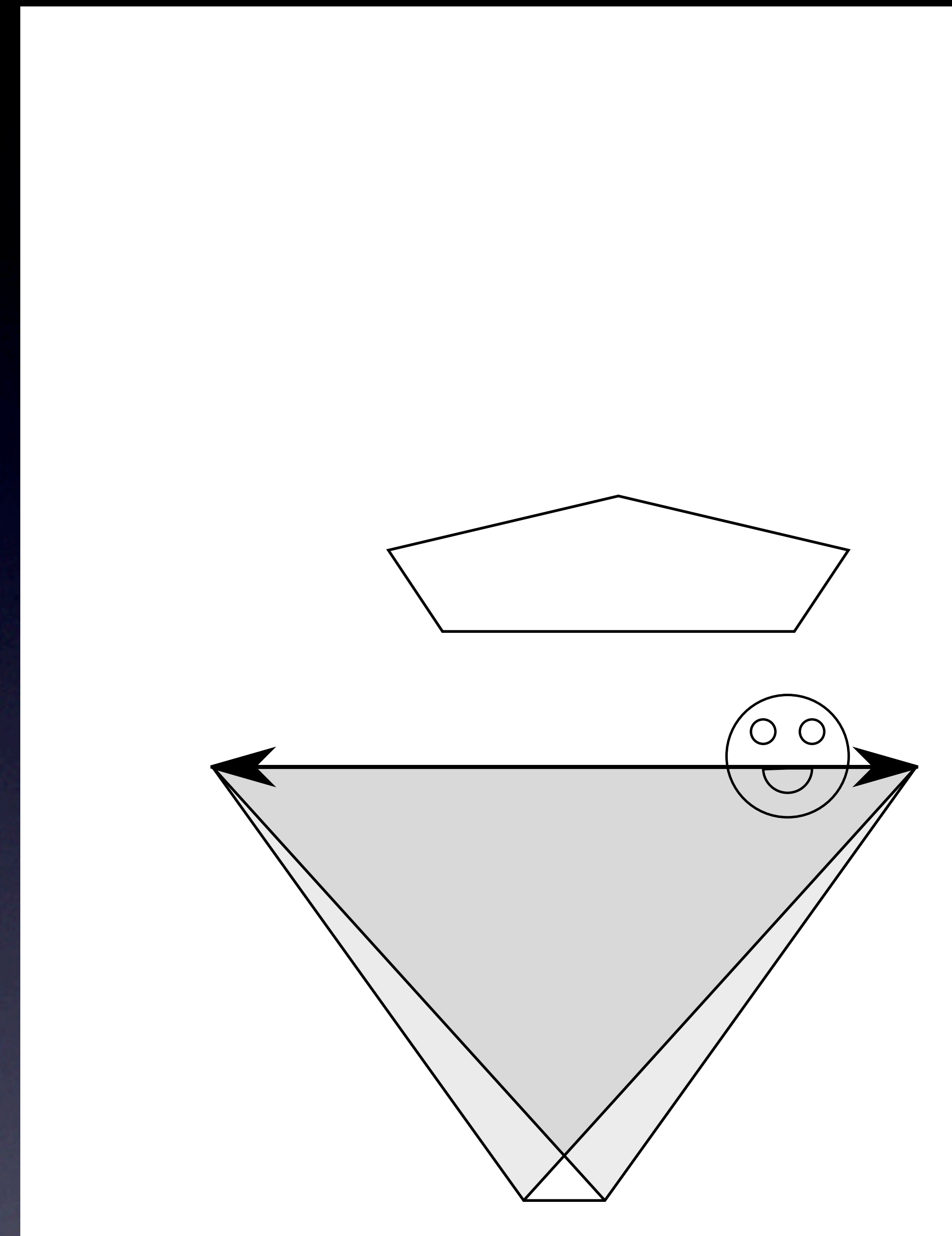

Viewing geometry

No distortion at all, but many objects cannot be seen in the original images... bad solution!

# New view synthesis: disparity remapping



Scene geometry



Viewing geometry

Best tradeoff: depth is not distorted, no divergence happens, only apparent width is distorted... like on any 2D image

# New view synthesis: how we do it

- Video-rate depth map computation
- Computation done on the GPU
- Will be included in Binocle DisparityTakker in 2011 for the 3DLive project
- Can also be done in a set-top box on the display side (by Technicolor)