Stereoscopic 3-D video for the human eyes

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research done within the 3DLive project

with
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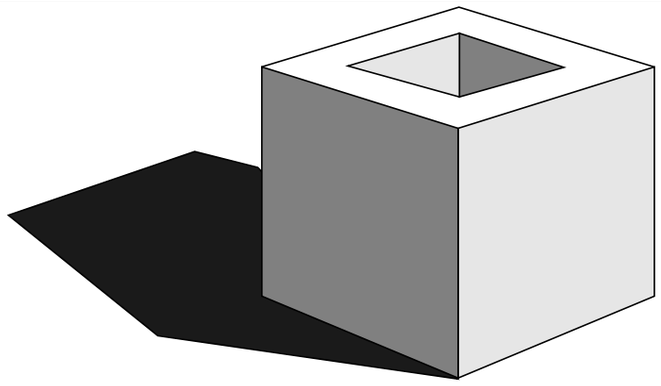
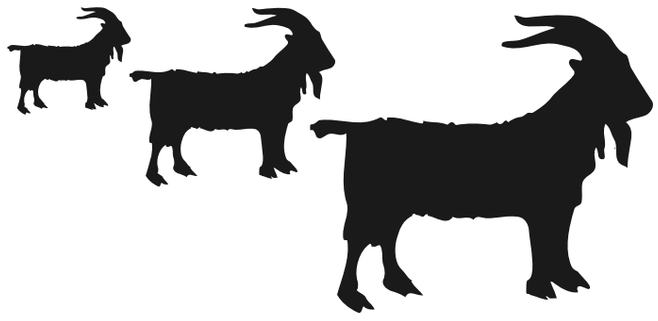
Shanghai, June 18th, 2010

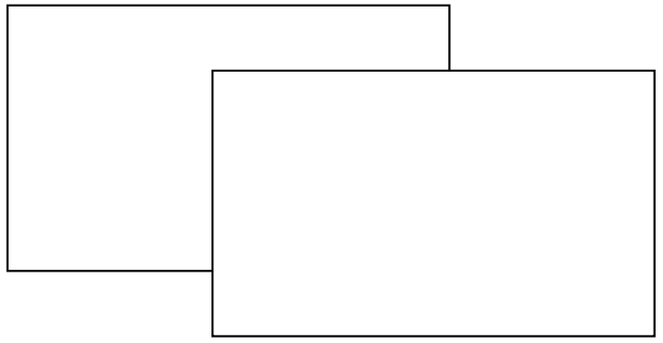
Three-Dimensional Depth Cues



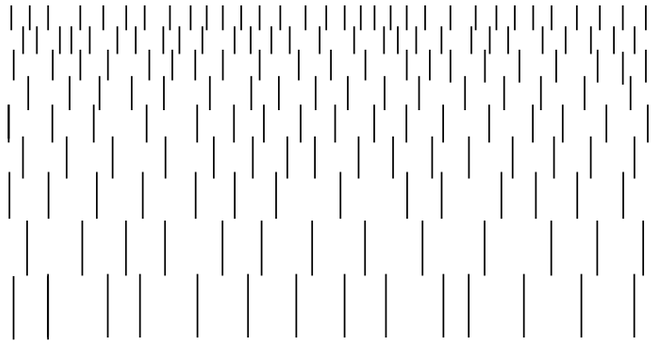
Light and shade



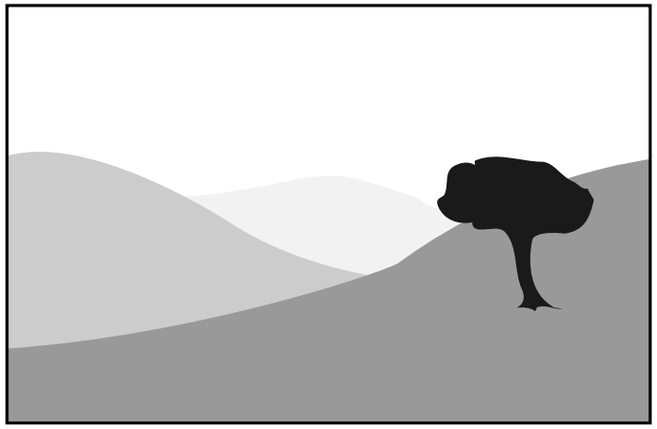
Relative size



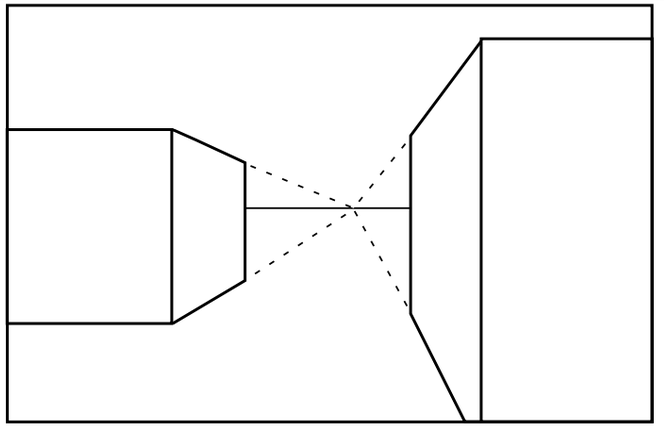
Interposition



Textural gradient



Aerial perspective



Perspective

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

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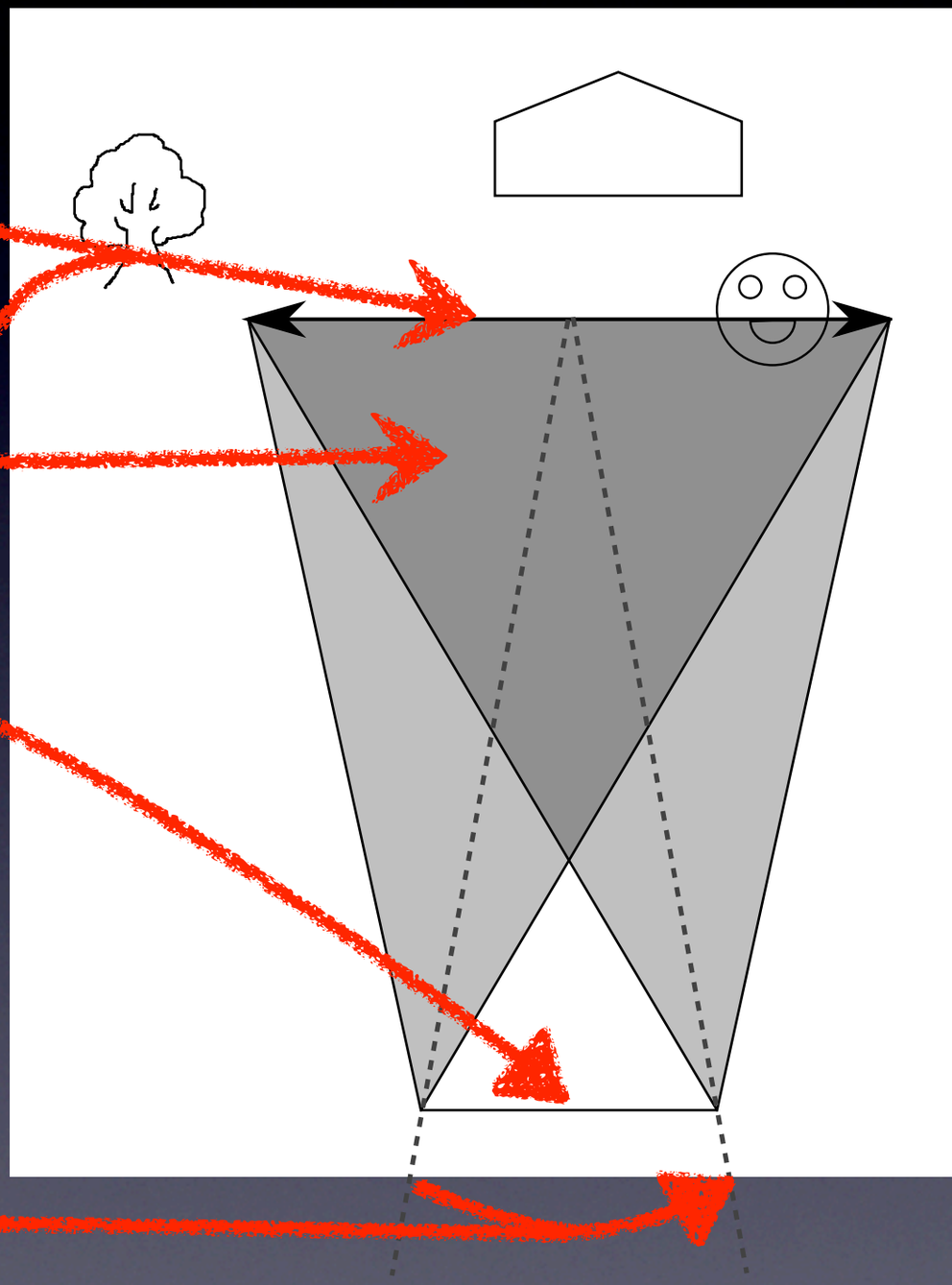
Depth of field as a depth cue: focus matters!

A few definitions

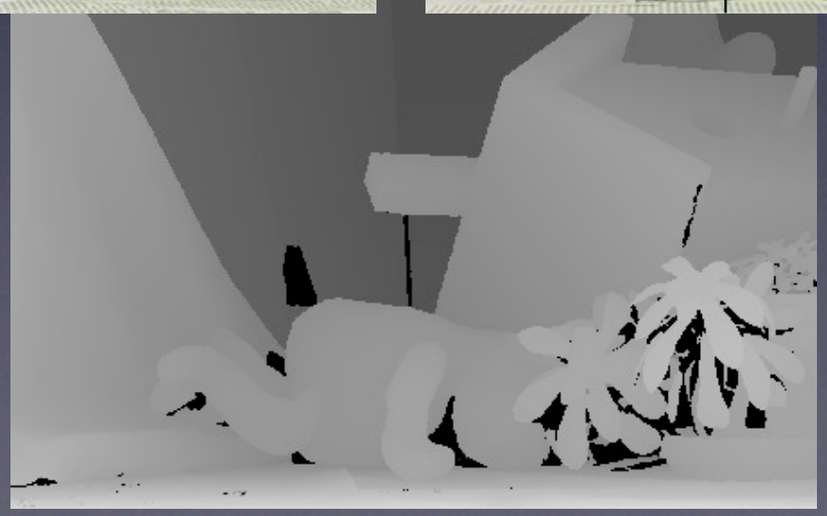
- Two cameras, two eyes
- Screen plane ... in the viewer space
- Plane of convergence .. in the scene space
- 3-D cone

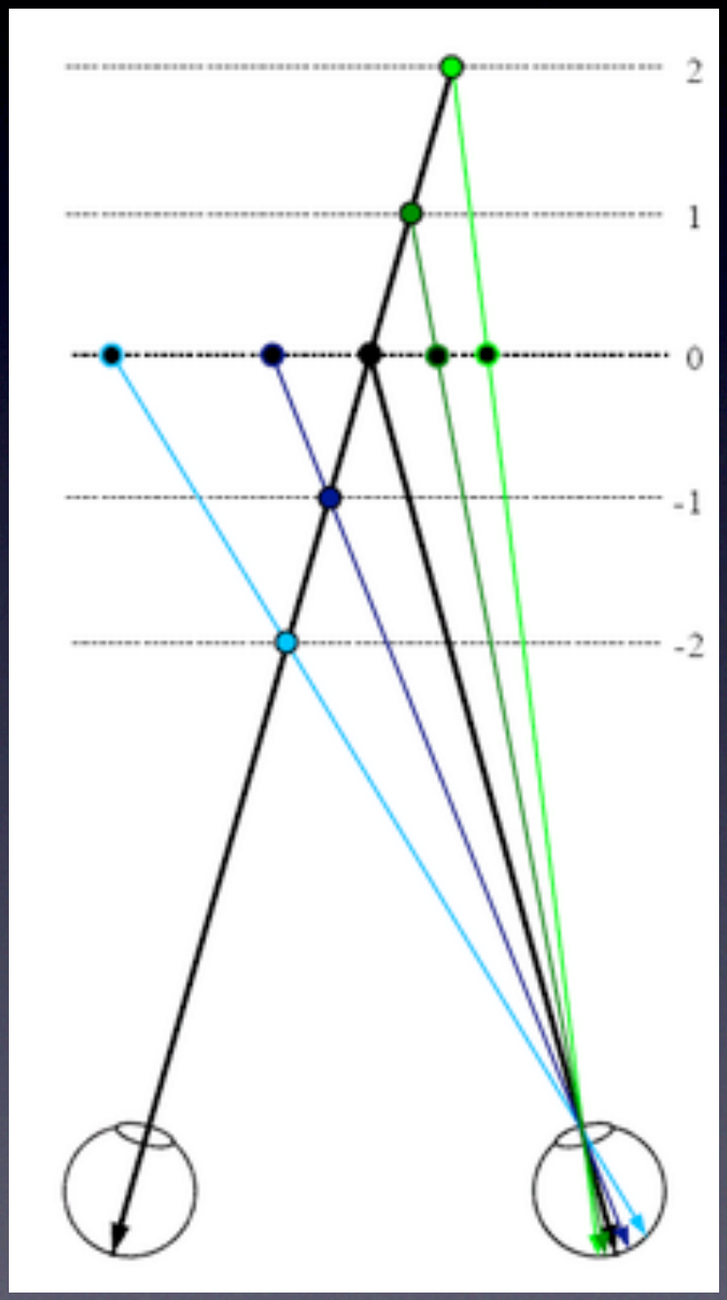


- Interocular / Interaxial
  - bigger than 65mm (can be 30m)$\Longrightarrow$ hyperstereo (or miniaturization)
  - smaller than 65mm (can be 0cm) $\Longrightarrow$ hypostereo (or gigantism)
- Convergence

Binocular disparity: why we see in 3D

- Objects at different depths cause different disparities





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left view

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right view

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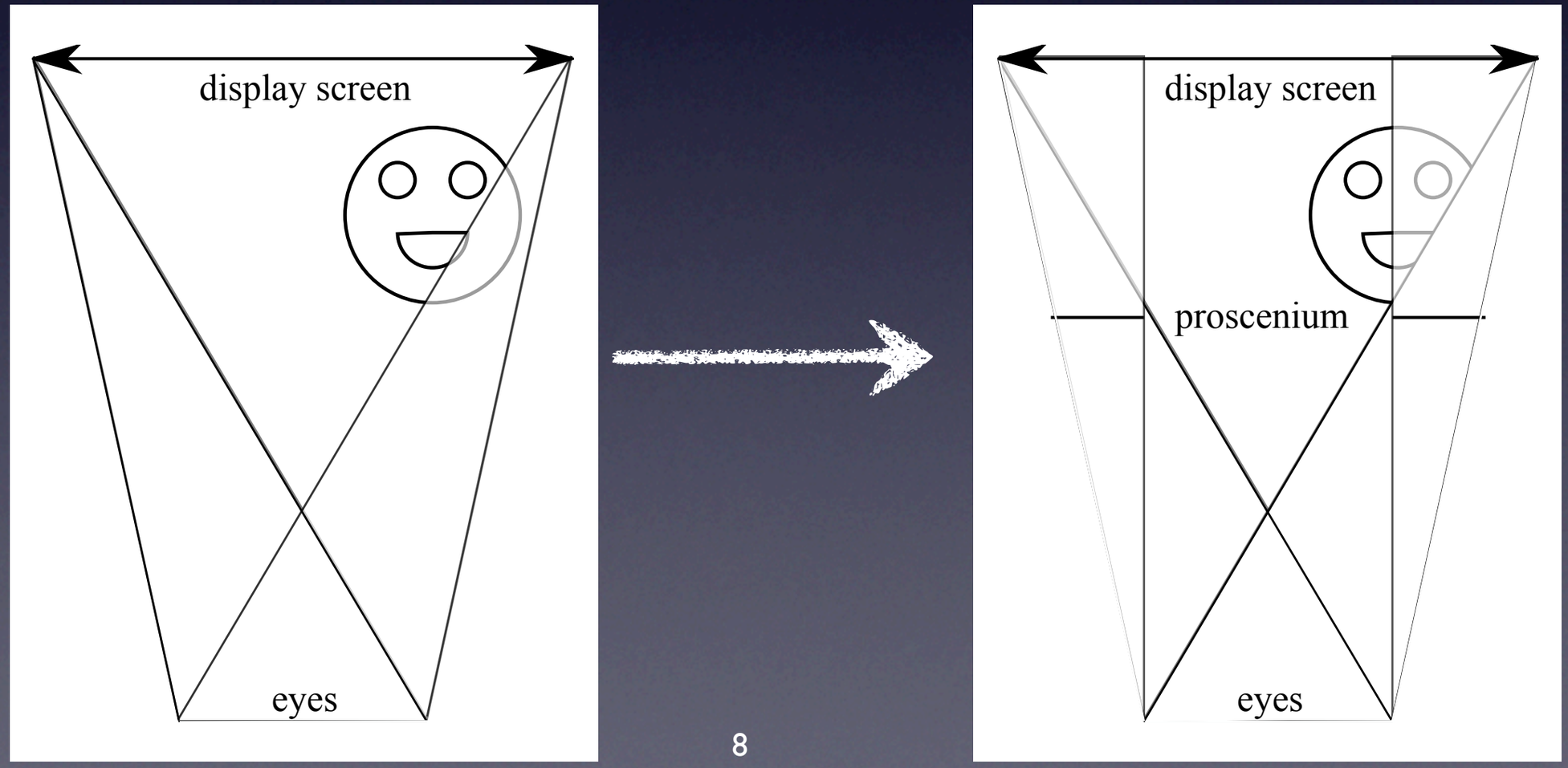
The proscenium arch (or stereoscopic window)

The screen is a window on the world

If object closer than convergence plane touches the image borders...

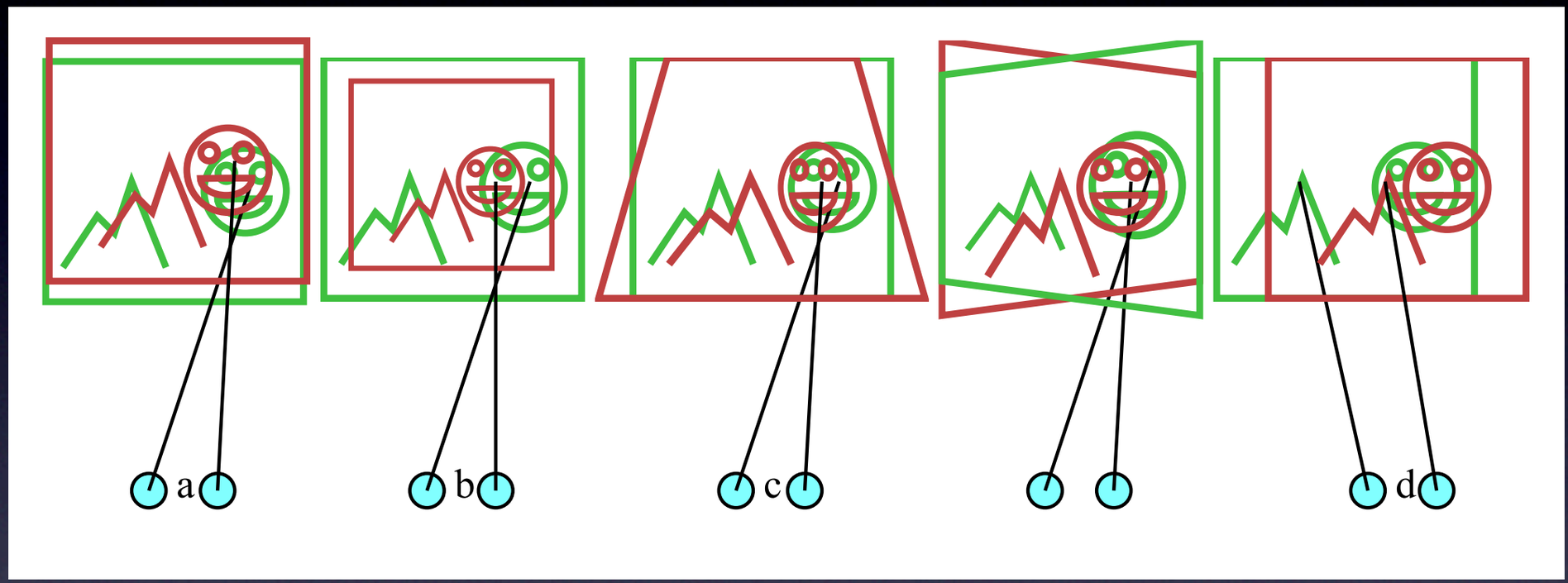
$\Longrightarrow$ Add black borders to move proscenium arch closer



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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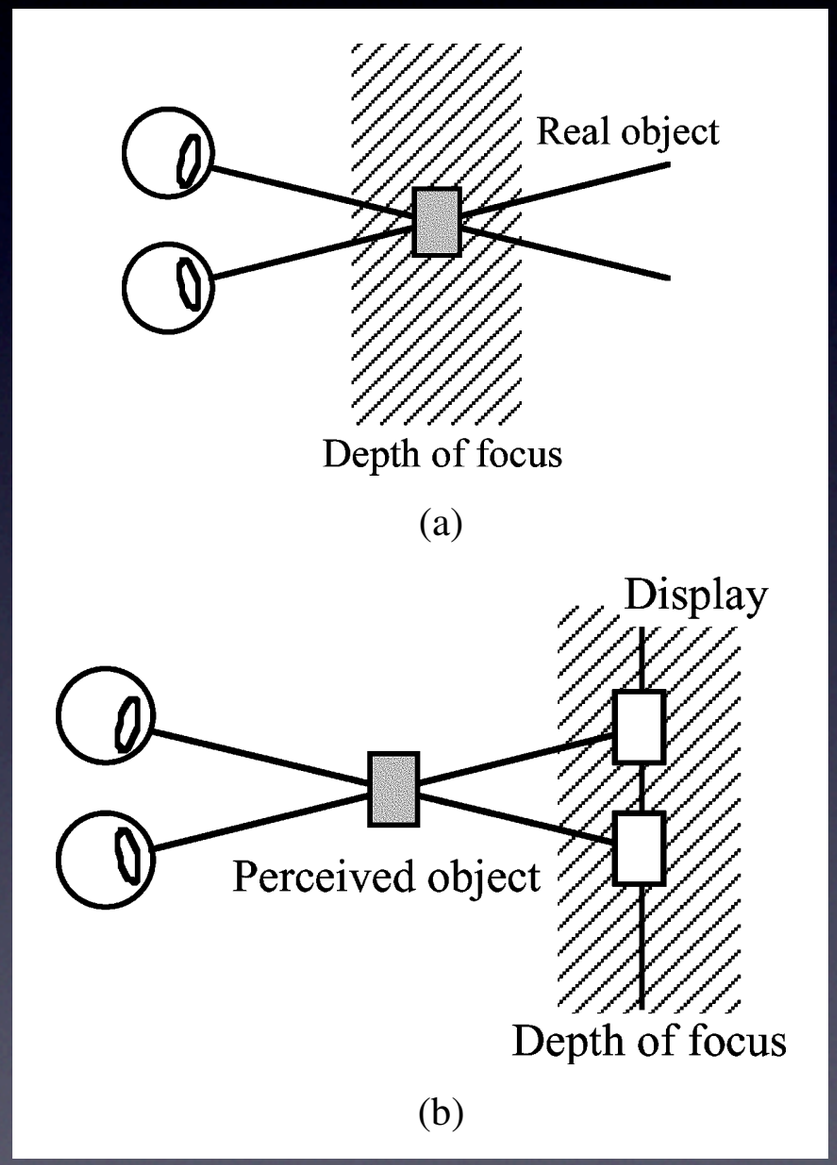
Visual fatigue (3)
accommodation and convergence discrepancy

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

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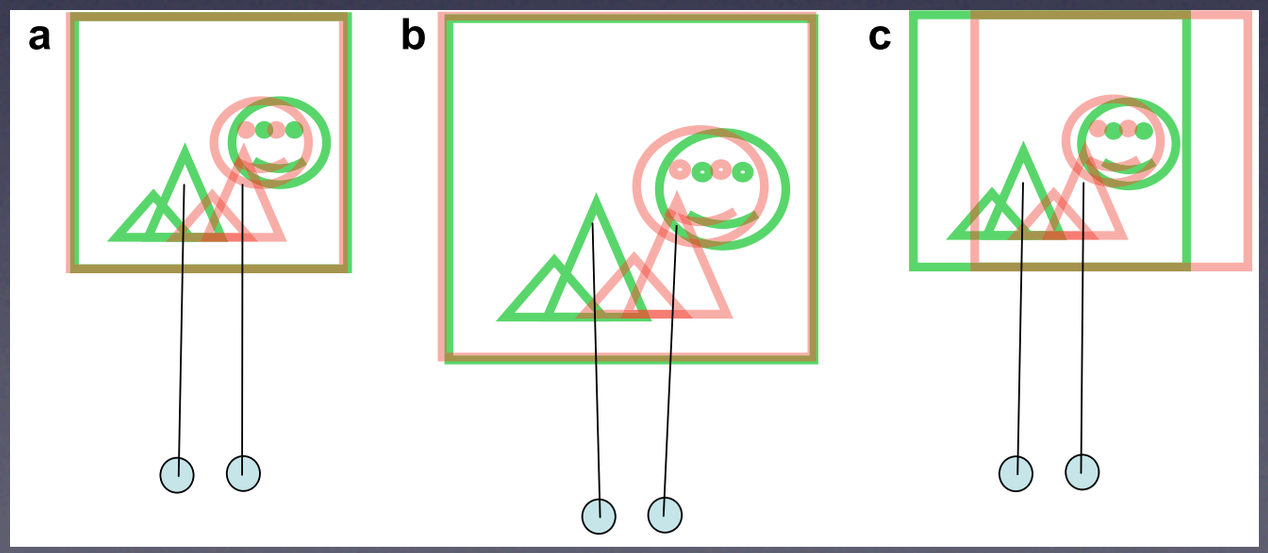
Visual fatigue (4)
screen size

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

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

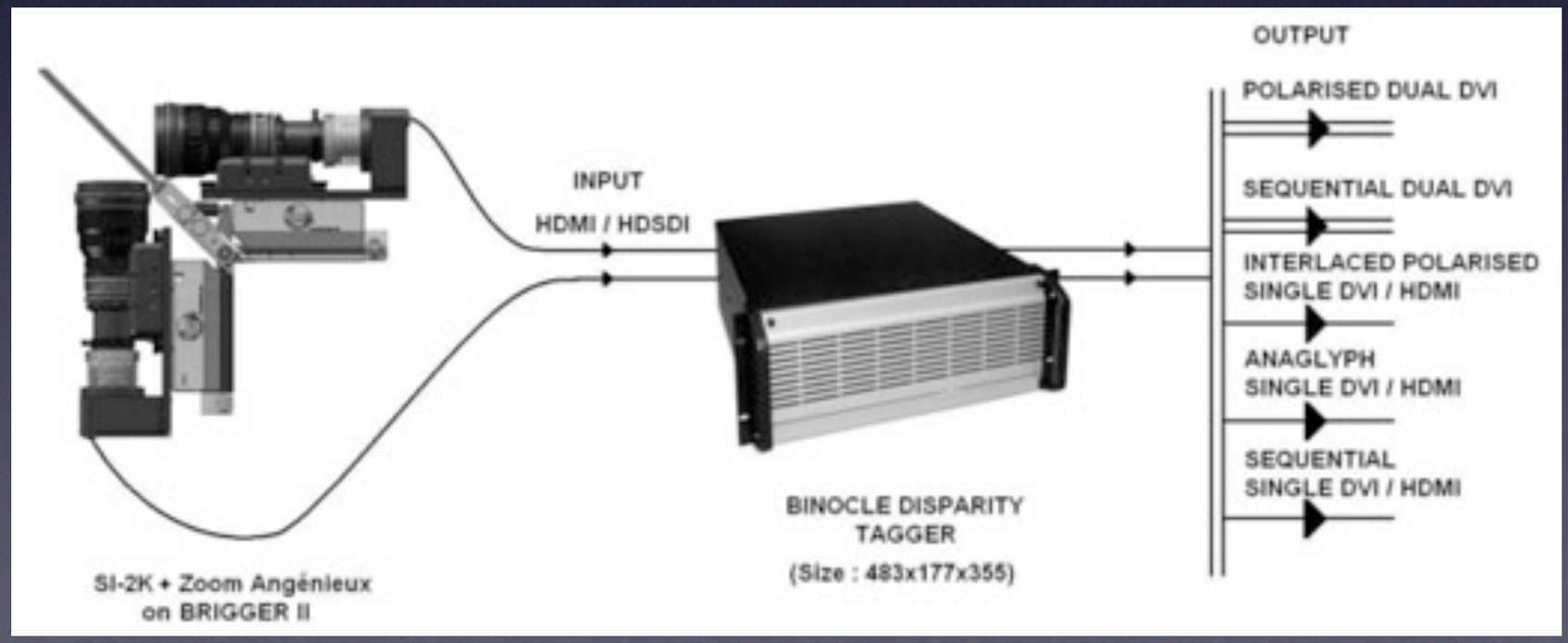
- Breaks the stereoscopic window
- Causes depth distortions



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**



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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)

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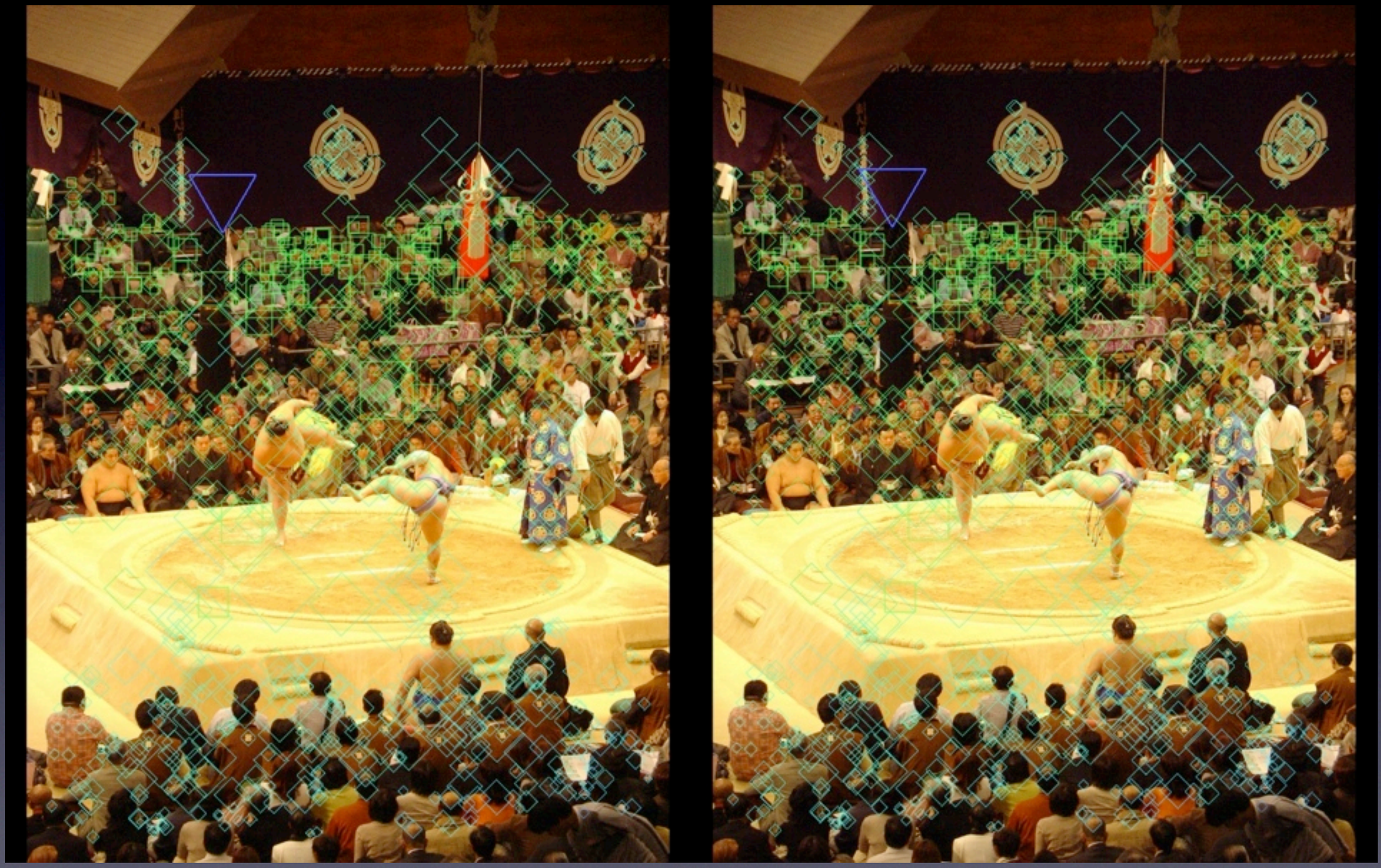

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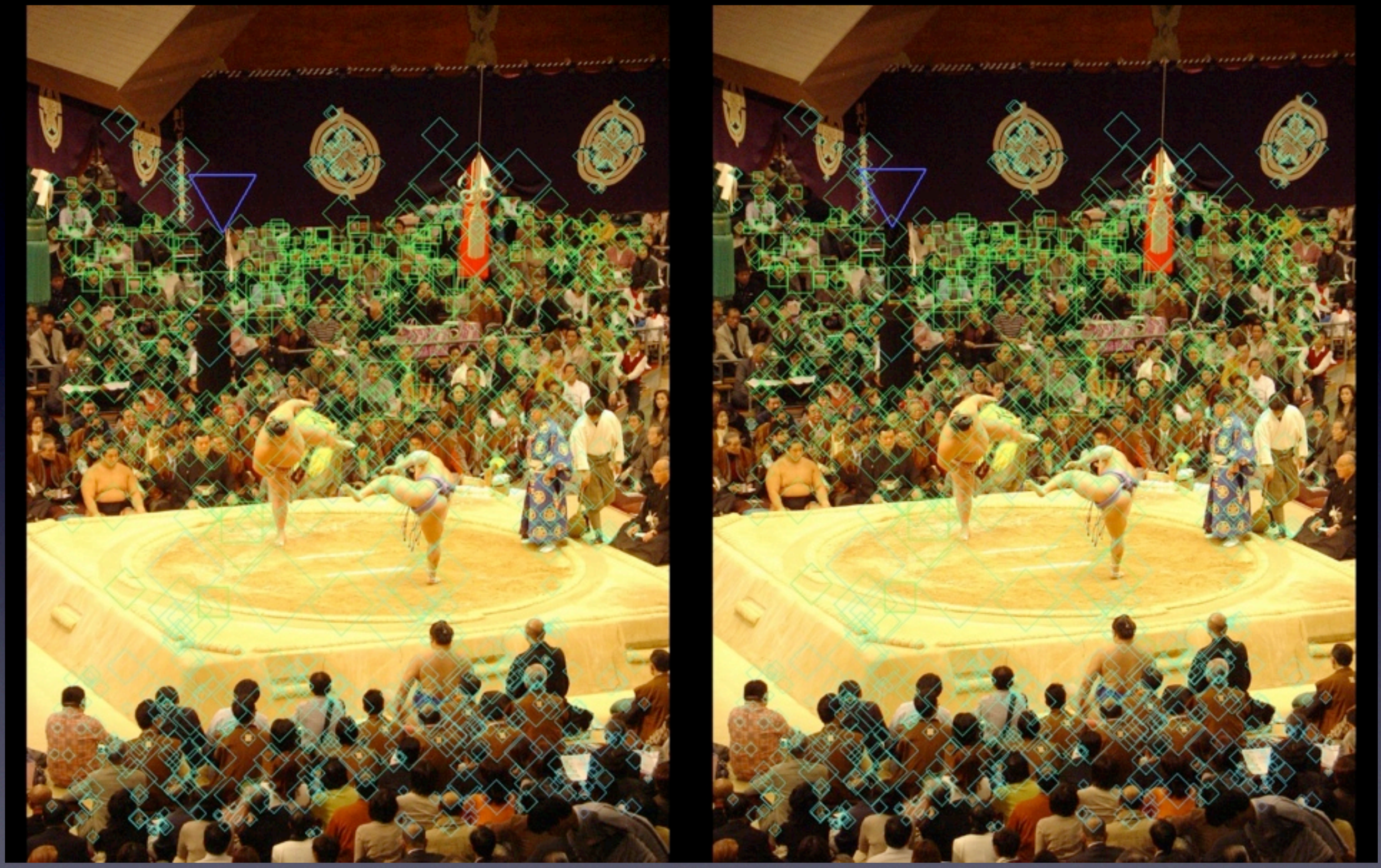

Alerts for a 4m wide screen

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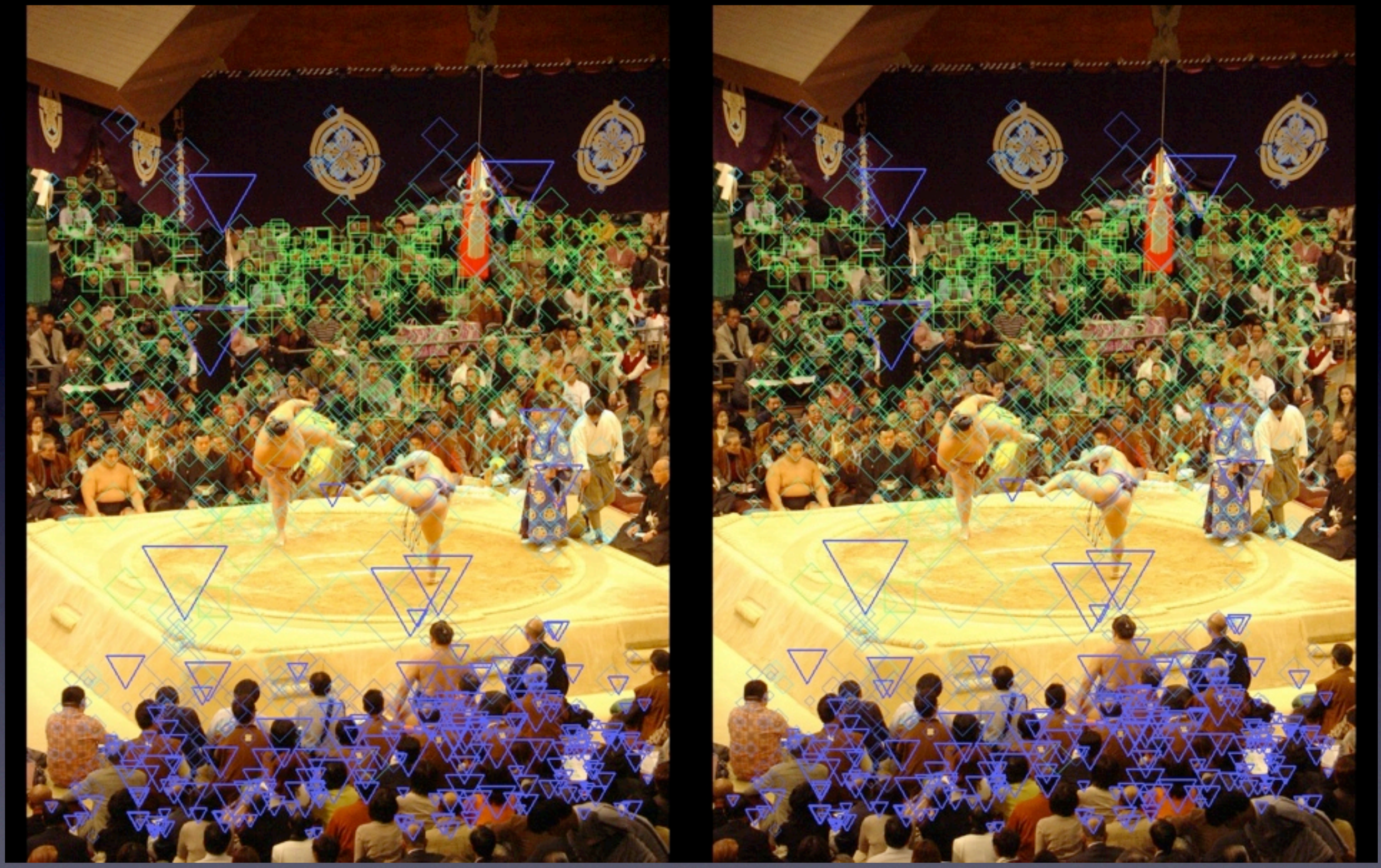

Alerts for a 10m wide screen: crowd too close!

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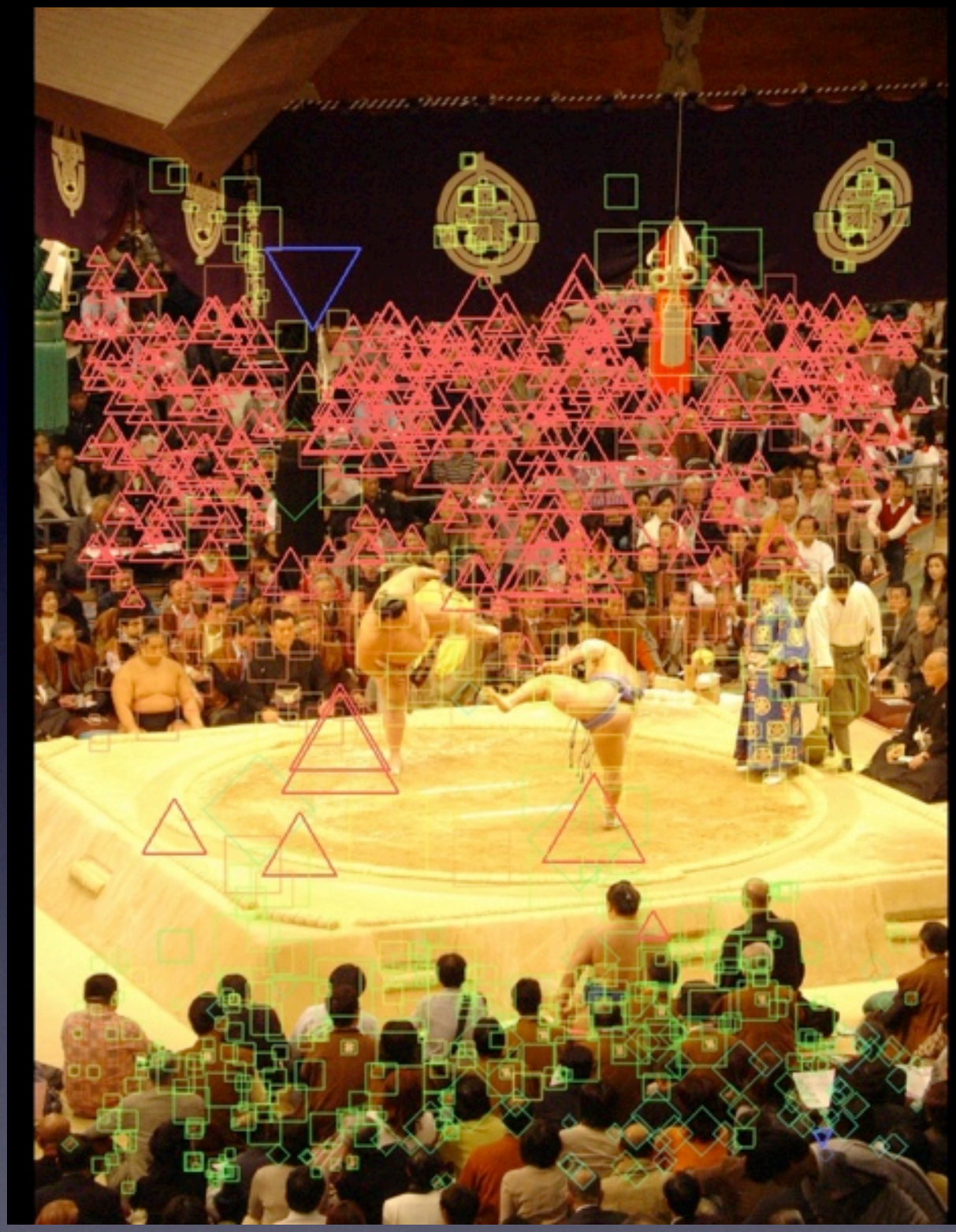

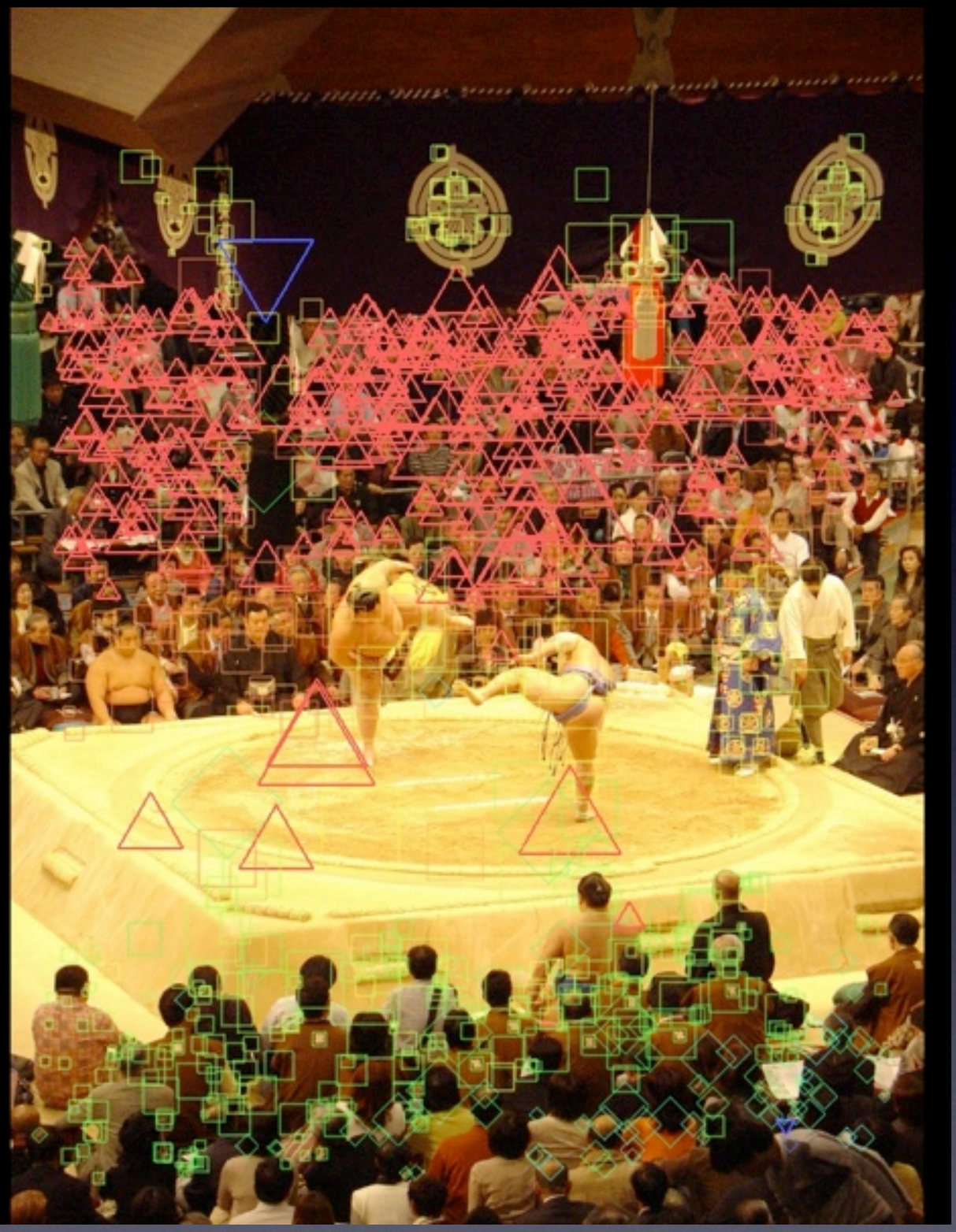

Alerts for a 10m wide screen + shift: divergence!

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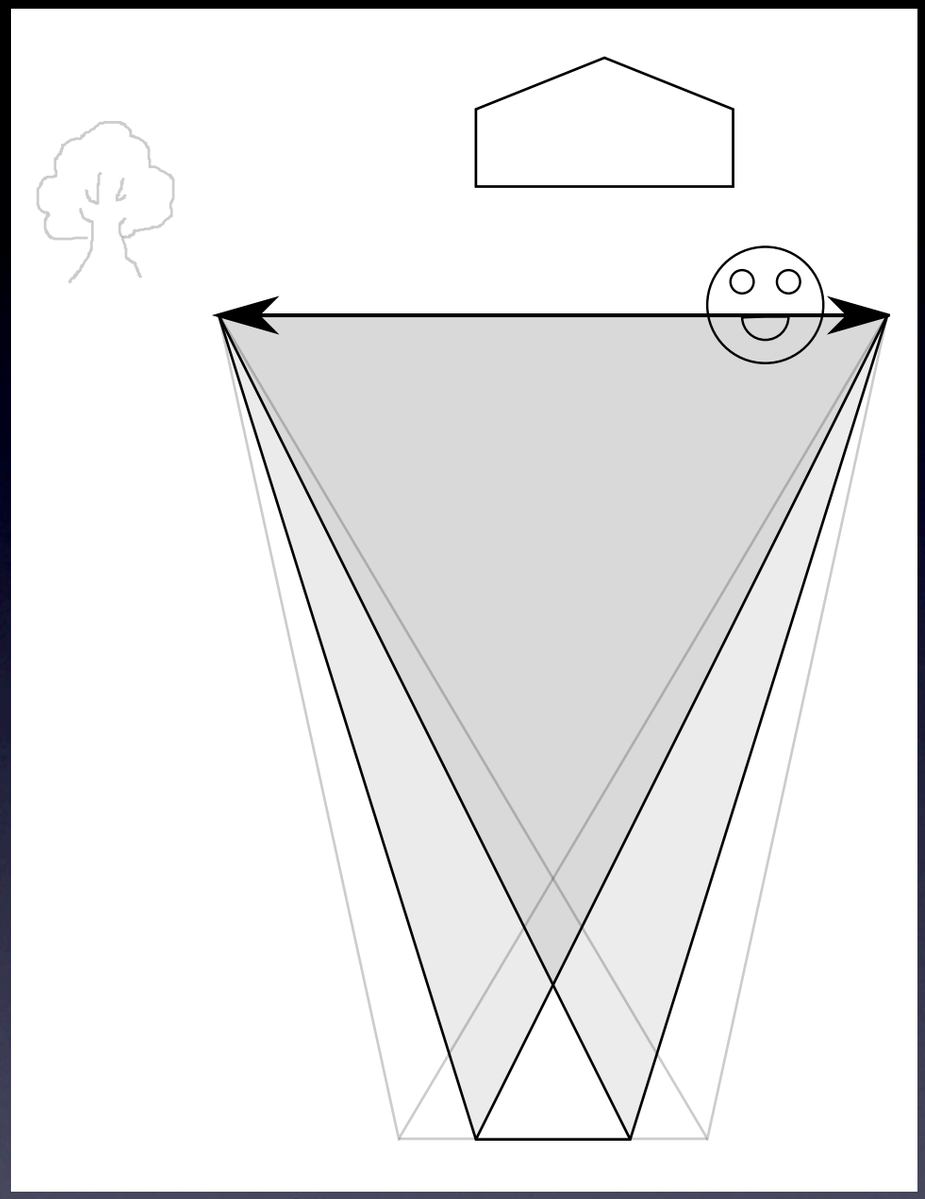
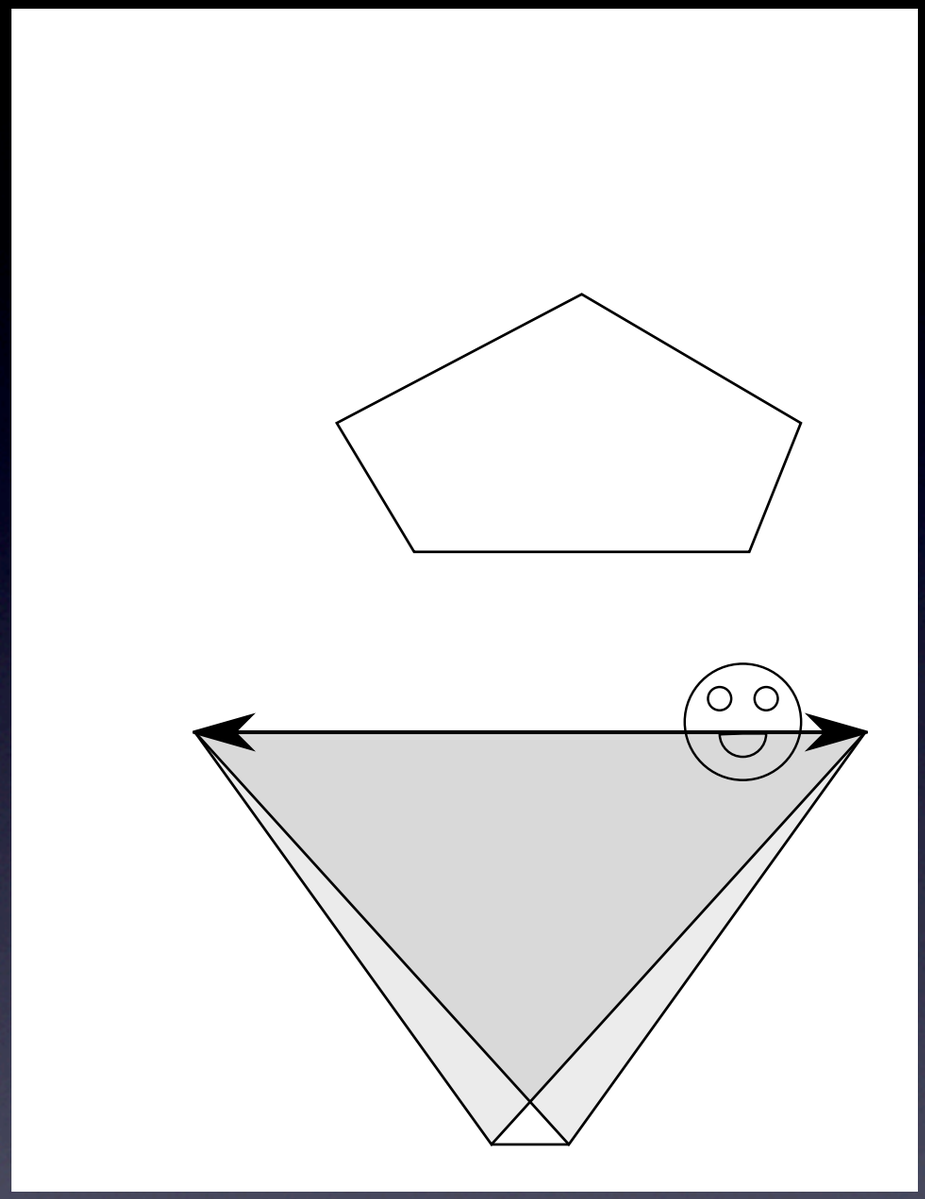
Perceived depth distortions

- 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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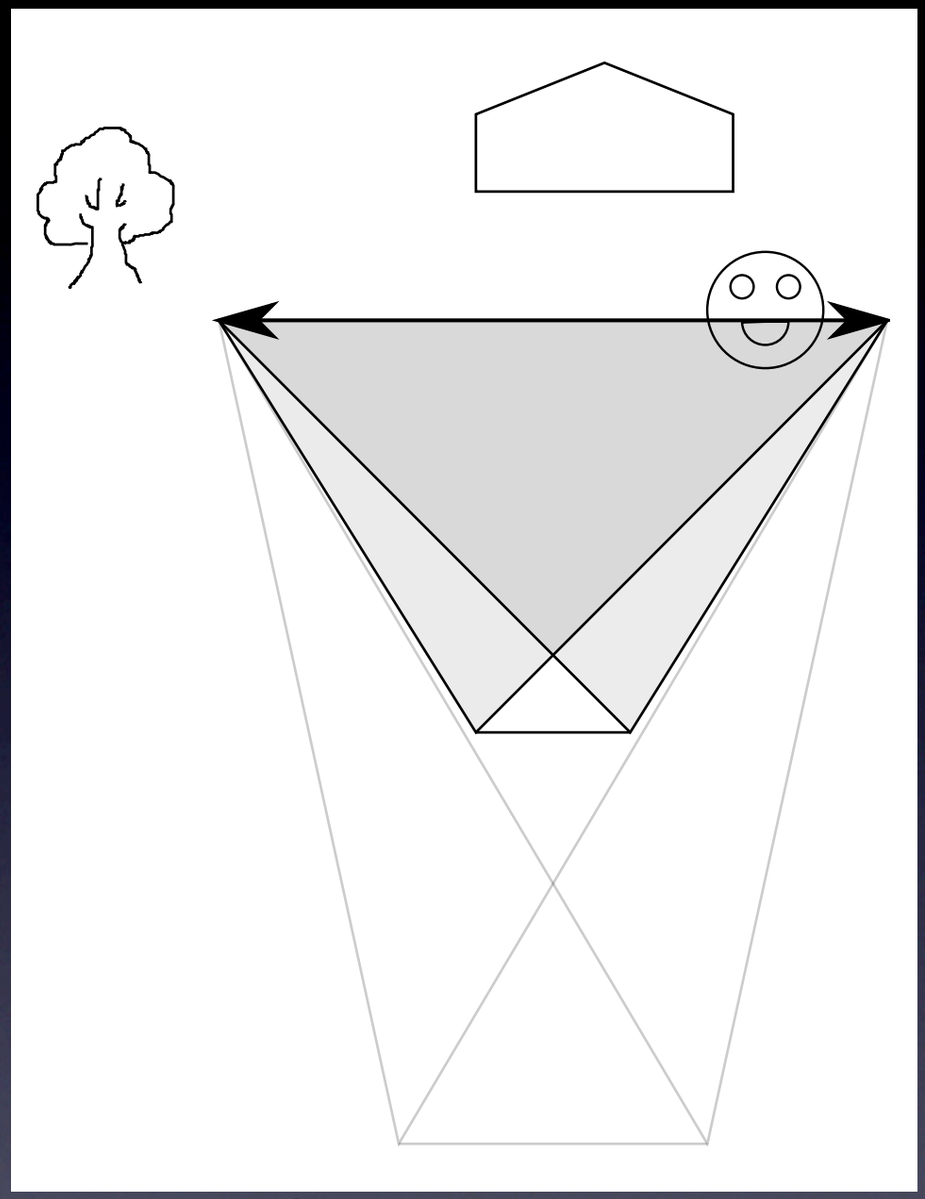
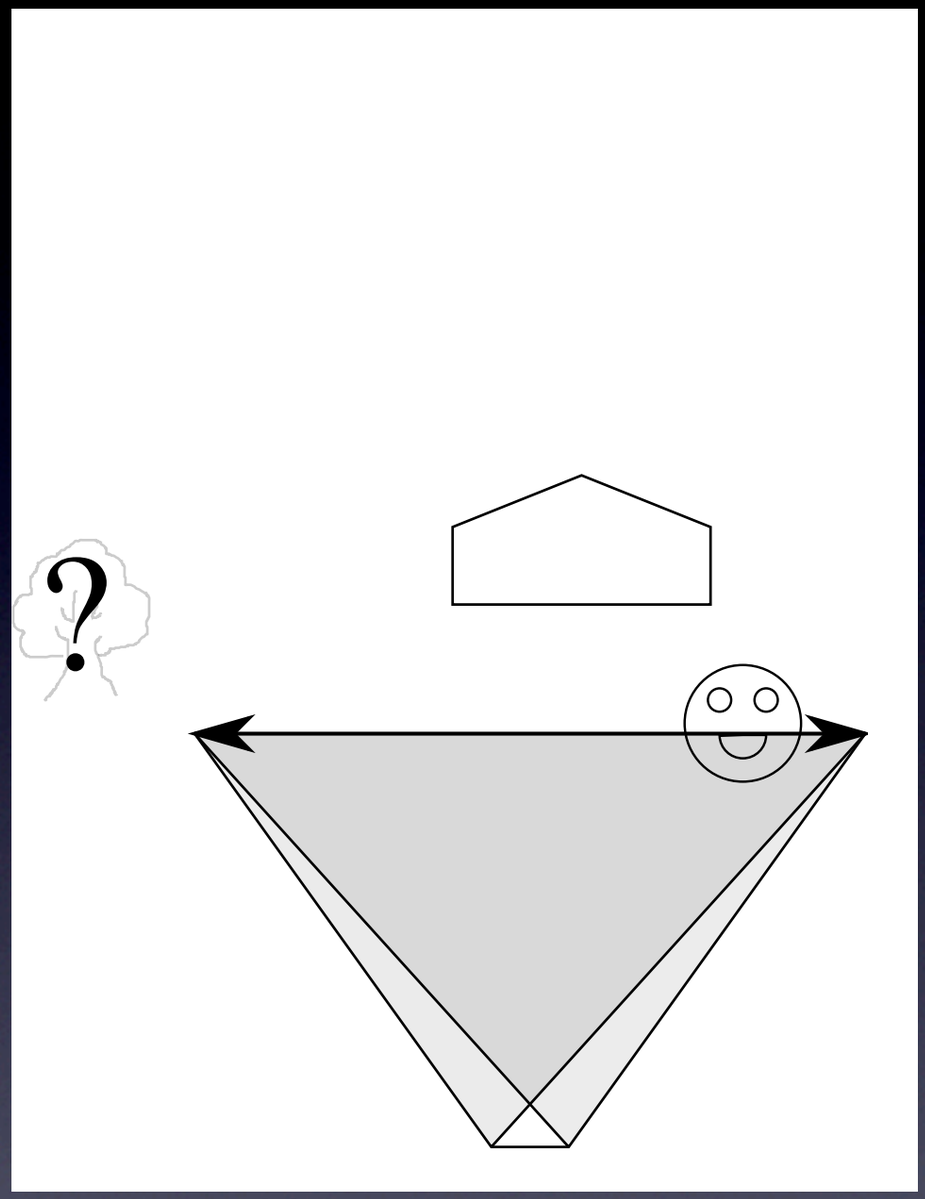
New view synthesis: viewpoint modification



Scene geometry



Viewing geometry

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

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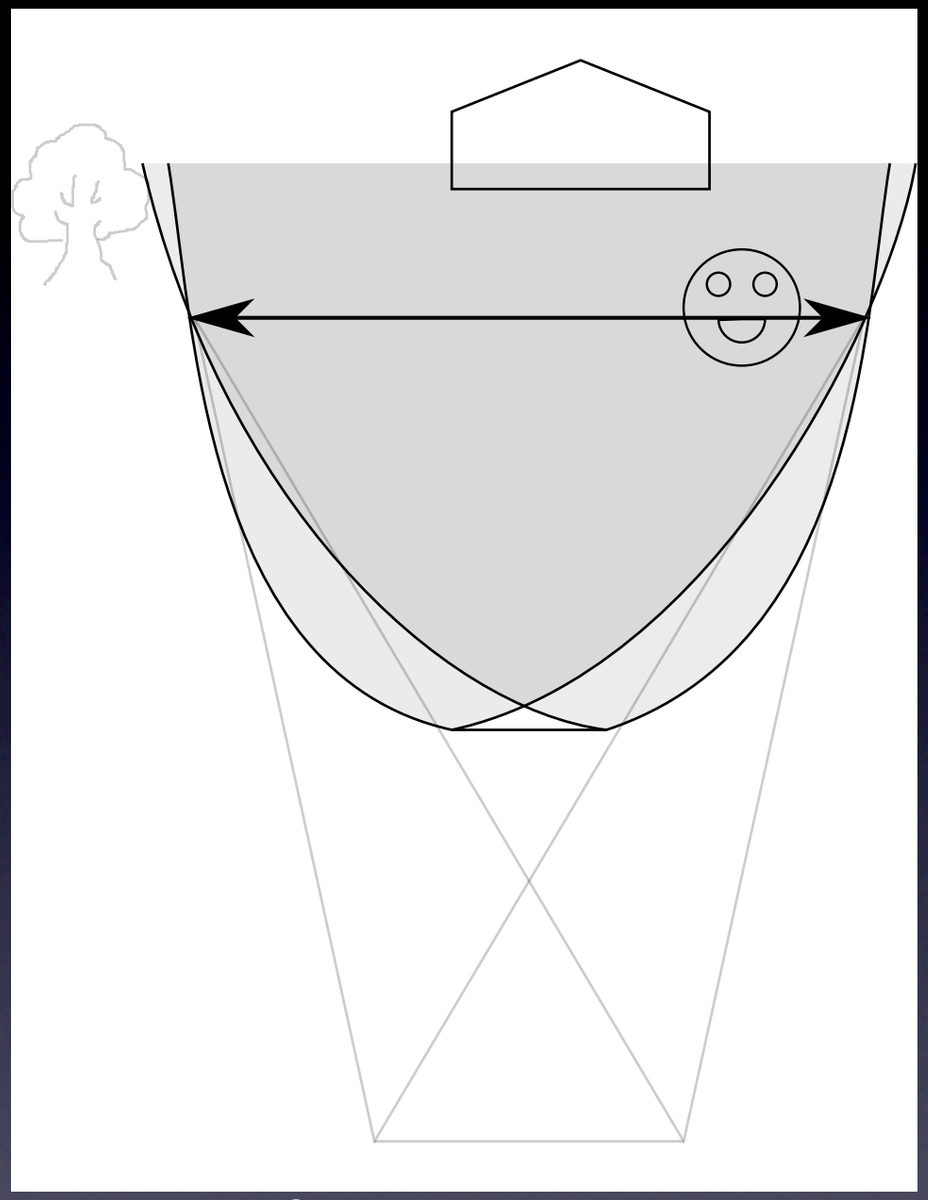
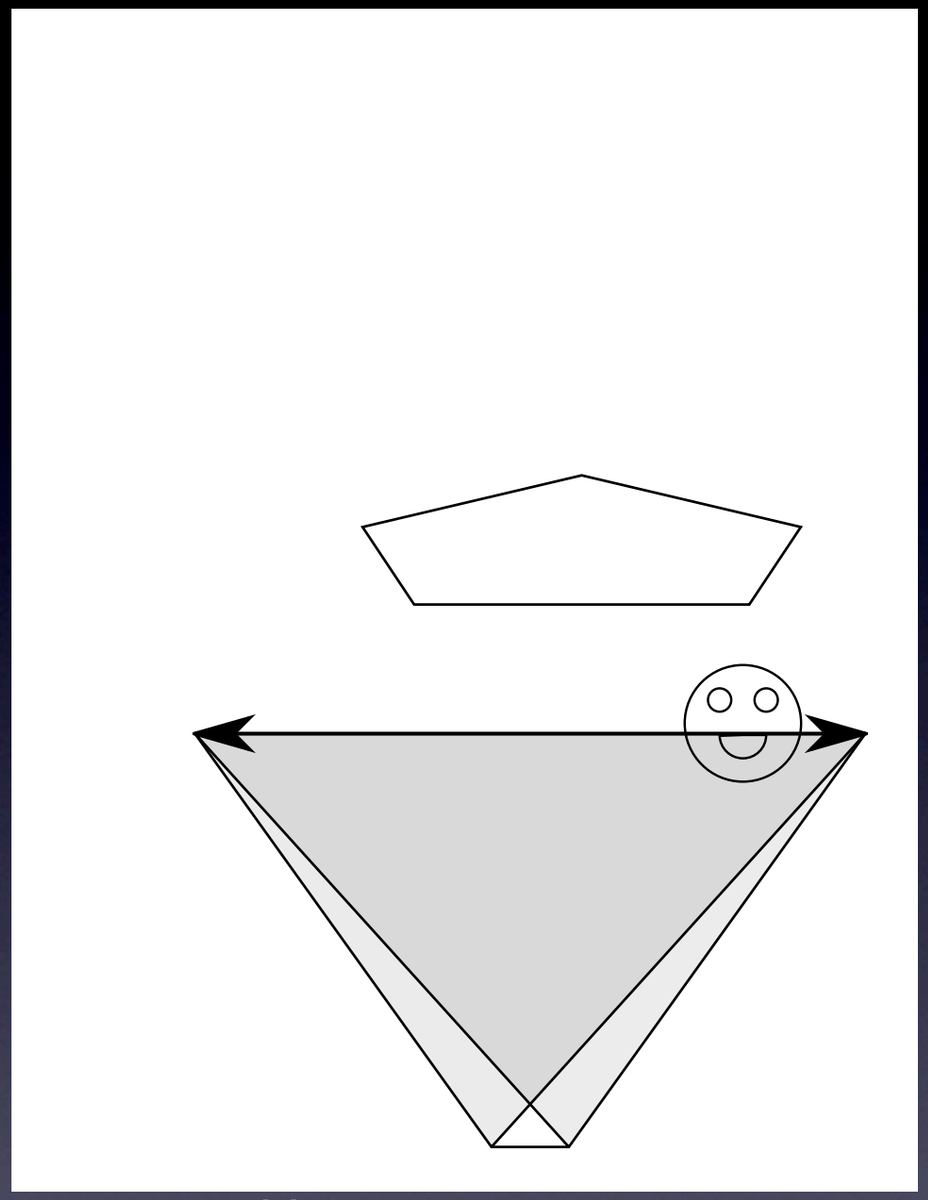
New view synthesis: disparity remapping



Scene geometry



Viewing geometry

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

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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)