UNIVERSITY OF CAMBRIDGE
COMPUTER LABORATORY

RAINBOW GRAPHICS GROUP

Advanced Graphics & Image Processing

Stereo Rendering

Part 1/3 – depth perception

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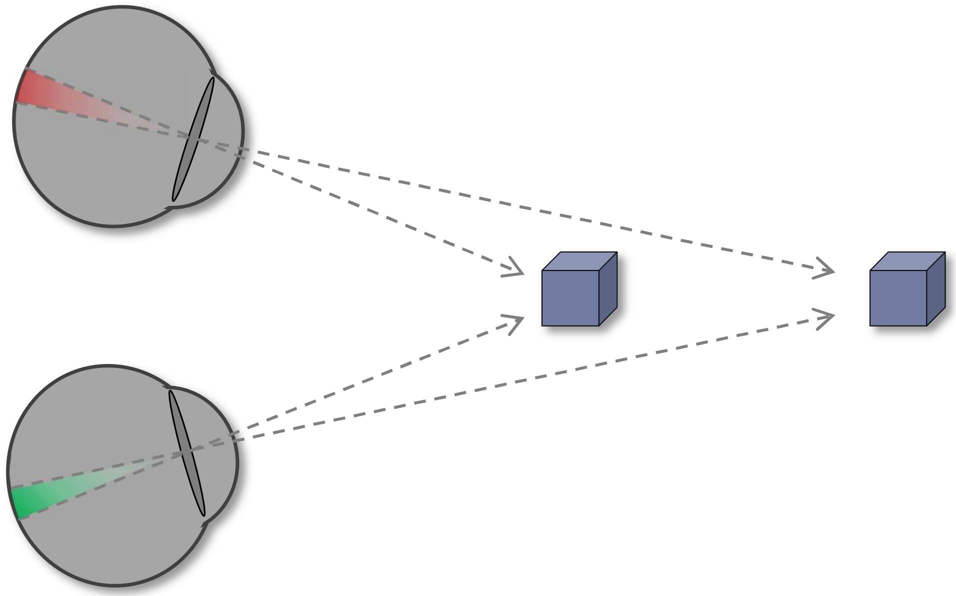
Depth perception

We see depth due to depth cues.

Stereoscopic depth cues:

binocular disparity



The slides in this section are the courtesy of Piotr Didyk (http://people.mpi-inf.mpg.de/~pdidyk/)

Depth perception

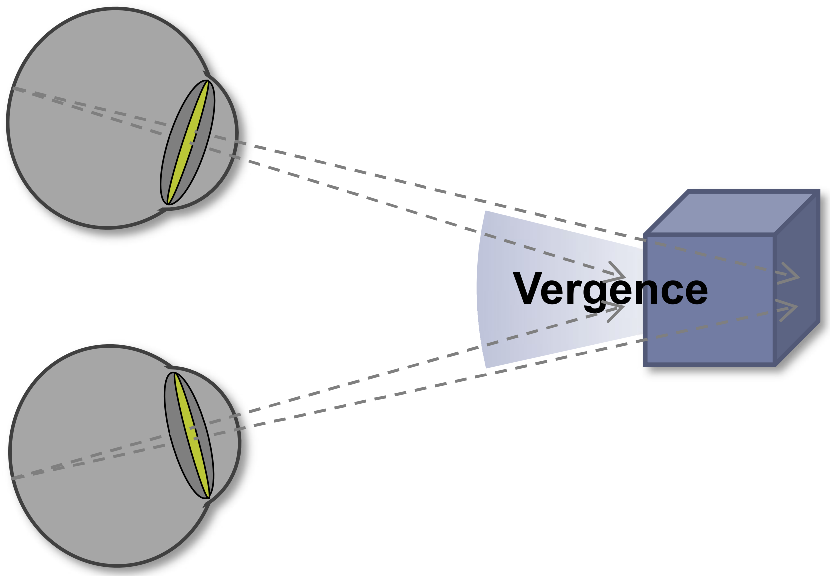
We see depth due to depth cues.

Stereoscopic depth cues:

binocular disparity

Ocular depth cues:

accommodation, vergence



Depth perception

We see depth due to depth cues.

Stereoscopic depth cues:

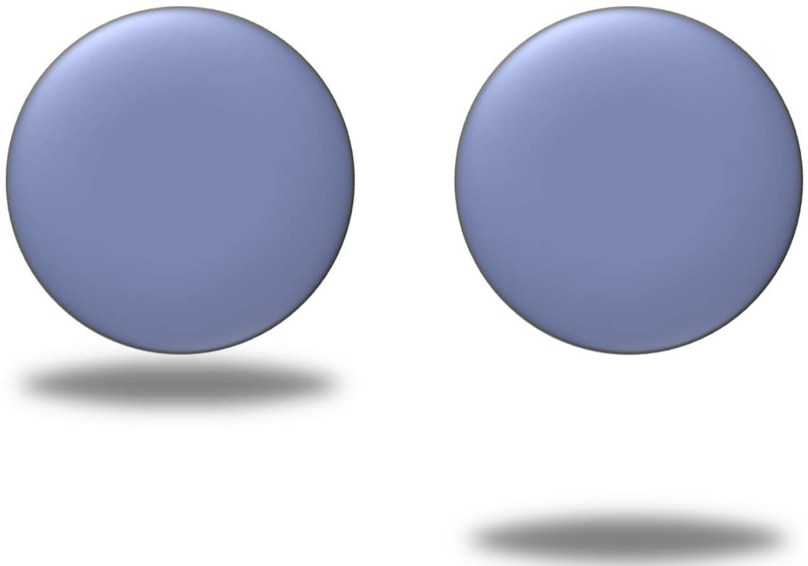
binocular disparity

Ocular depth cues:

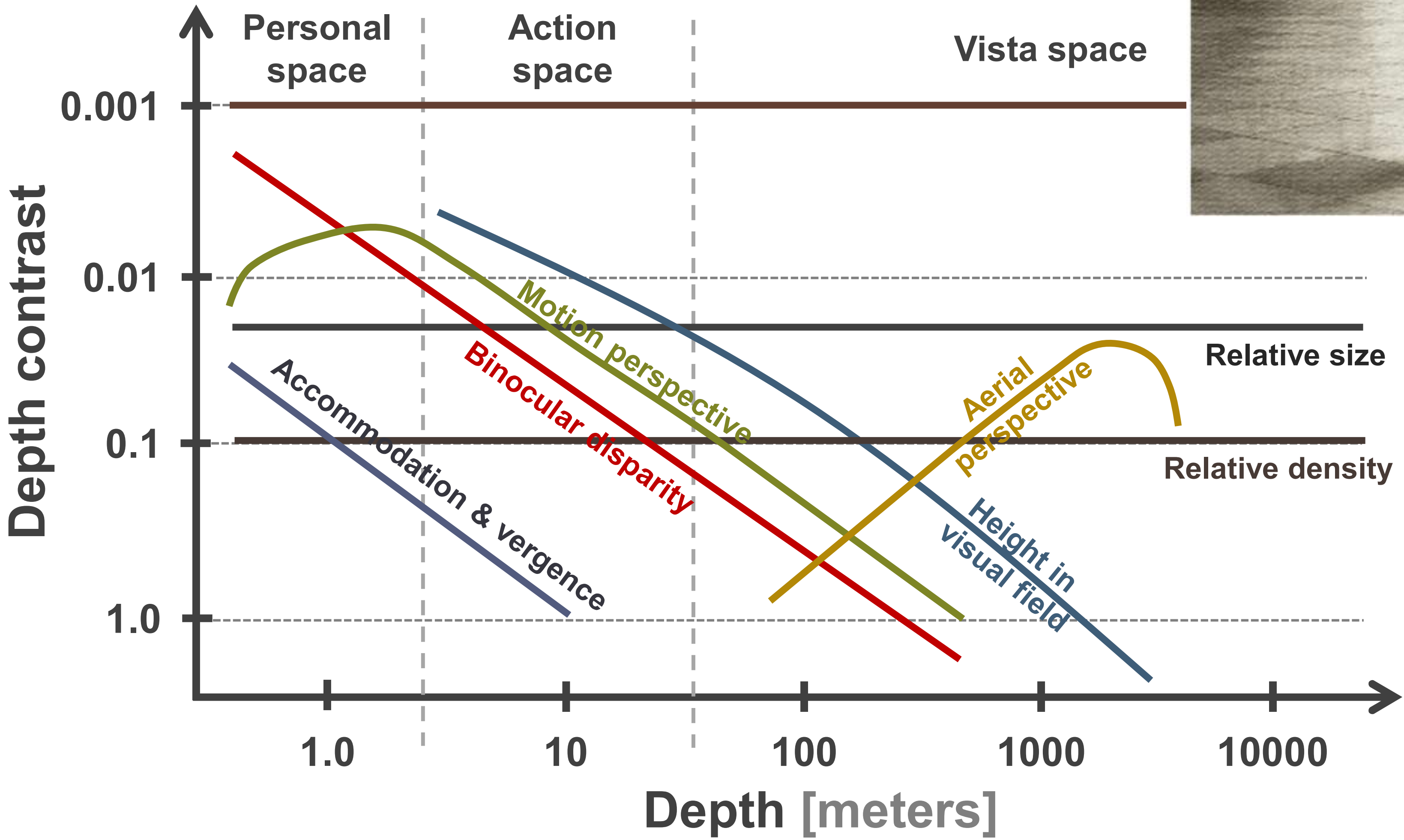
accommodation, vergence

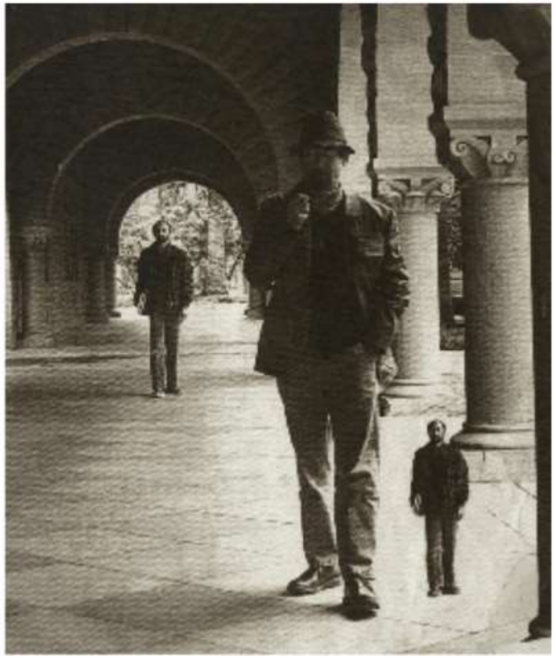
Pictorial depth cues:

occlusion, size, shadows…



Cues sensitivity





"Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth"
by Cutting and Vishton [1995]

Depth perception

We see depth due to depth cues.

Stereoscopic depth cues:

binocular disparity

Ocular depth cues:

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Pictorial depth cues:

occlusion, size, shadows…

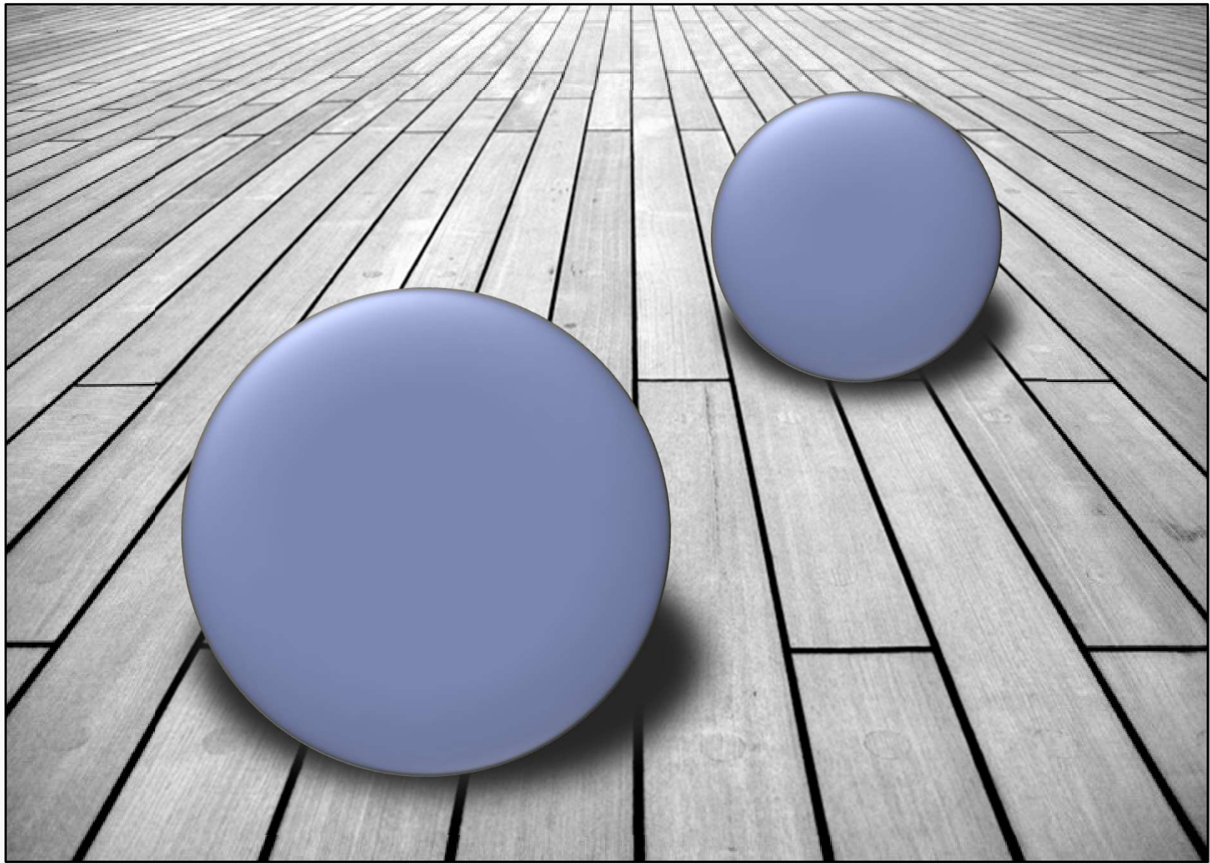
Challenge:
Consistency is required!

Simple conflict example

Present cues:

- Size
- Shadows
- Perspective

- **Occlusion**



Disparity & occlusion conflict

Objects in front

Disparity & occlusion conflict

Disparity & occlusion conflict

Depth perception

We see depth due to depth cues.

Stereoscopic depth cues:
binocular disparity

Ocular depth cues:
accommodation, vergence

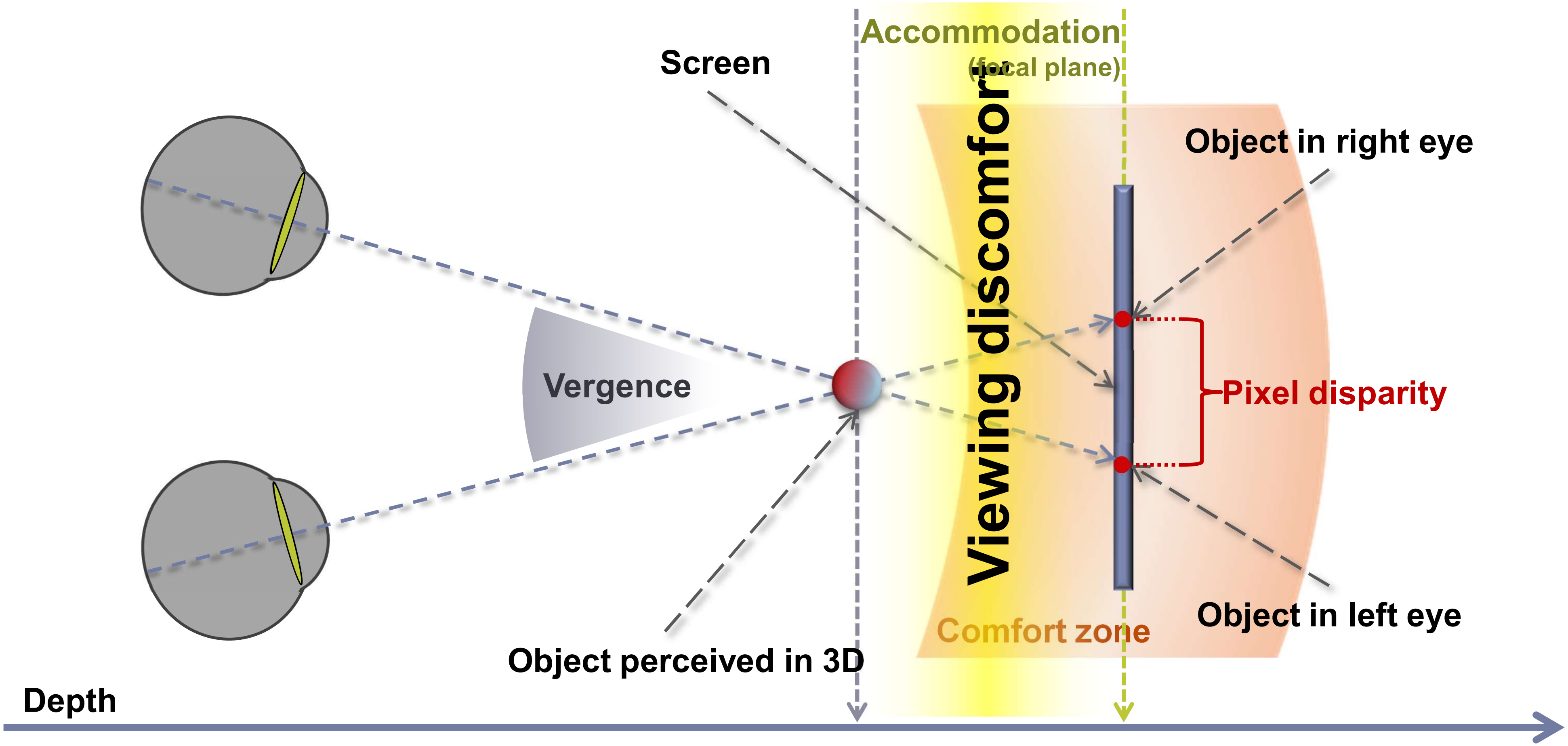
→ **Require 3D space**

We cheat our Visual System!

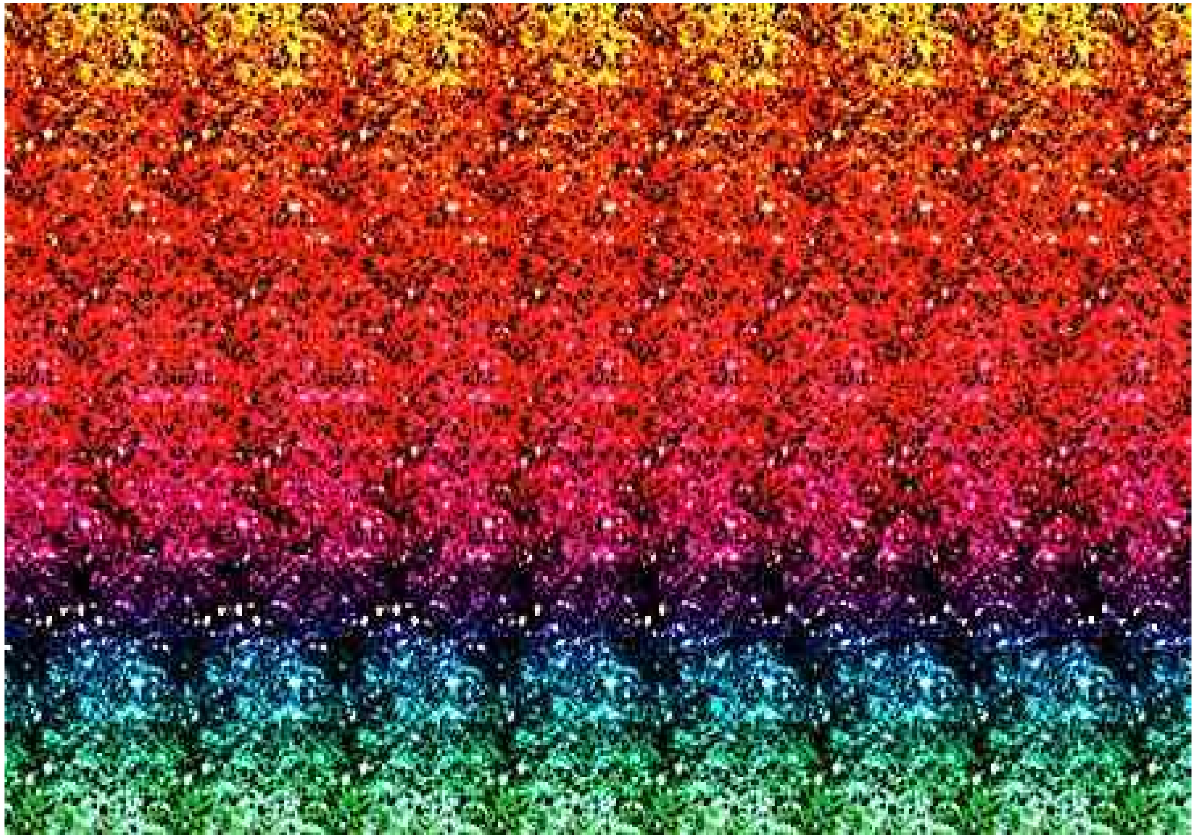
Pictorial depth cues:
occlusion, size, shadows…

→ **Reproducible on a flat displays**

Cheating our HVS

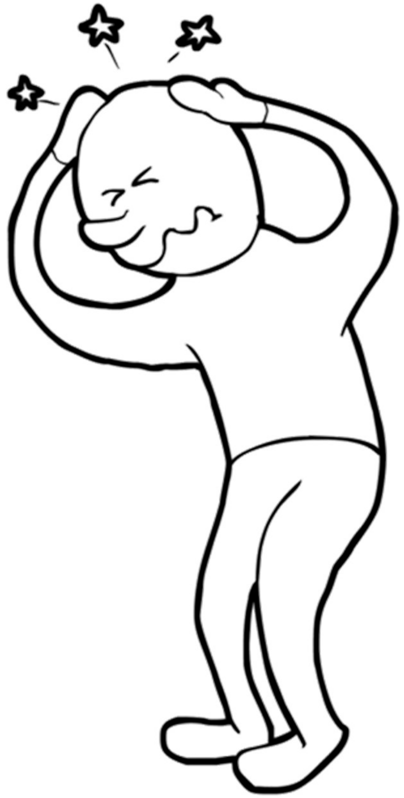


Single Image Random Dot Stereograms



- Fight the vergence vs. accommodation conflict to see the hidden image

Viewing discomfort

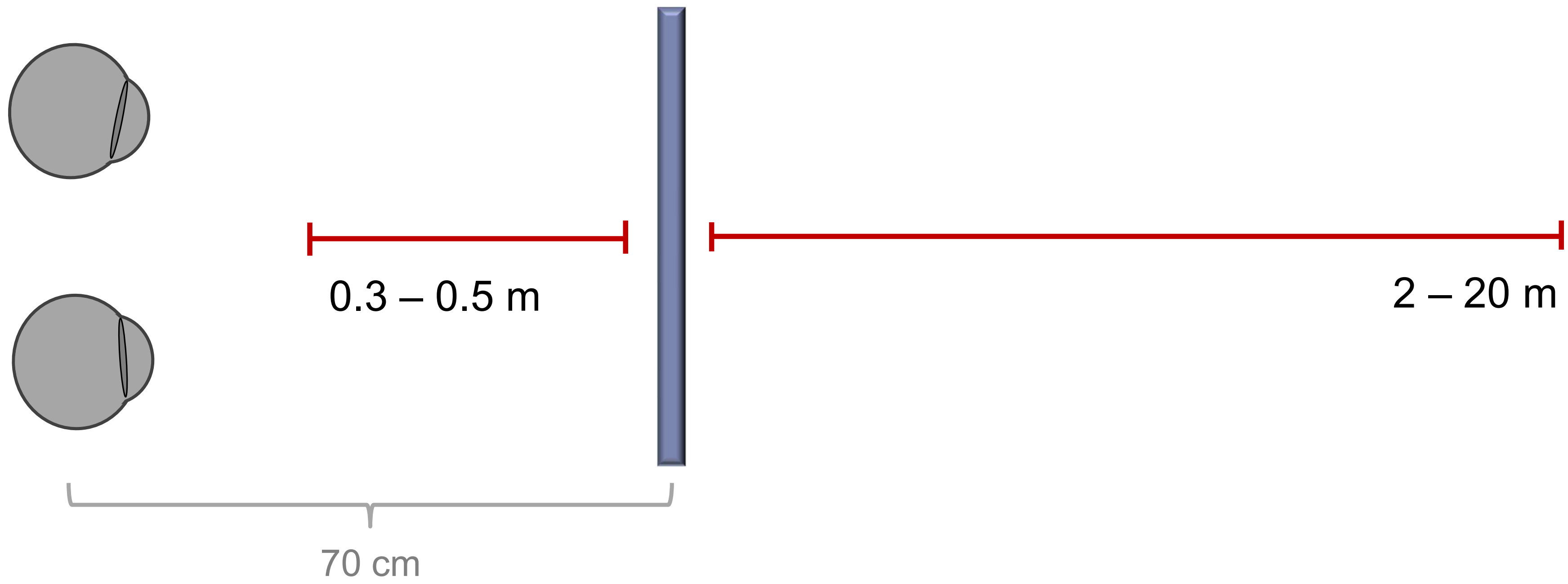


Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition

Simple scene



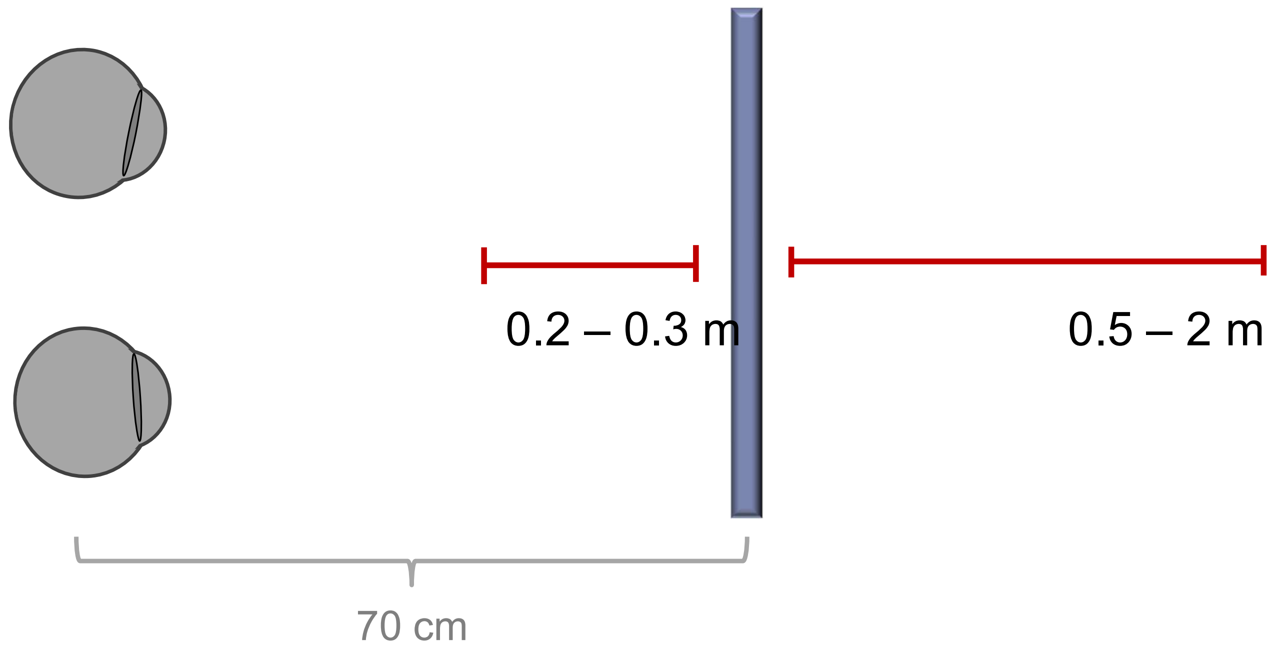
"Controlling Perceived Depth in Stereoscopic Images" by Jones et al. 2001

Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition

Simple scene, user allowed to look away from screen



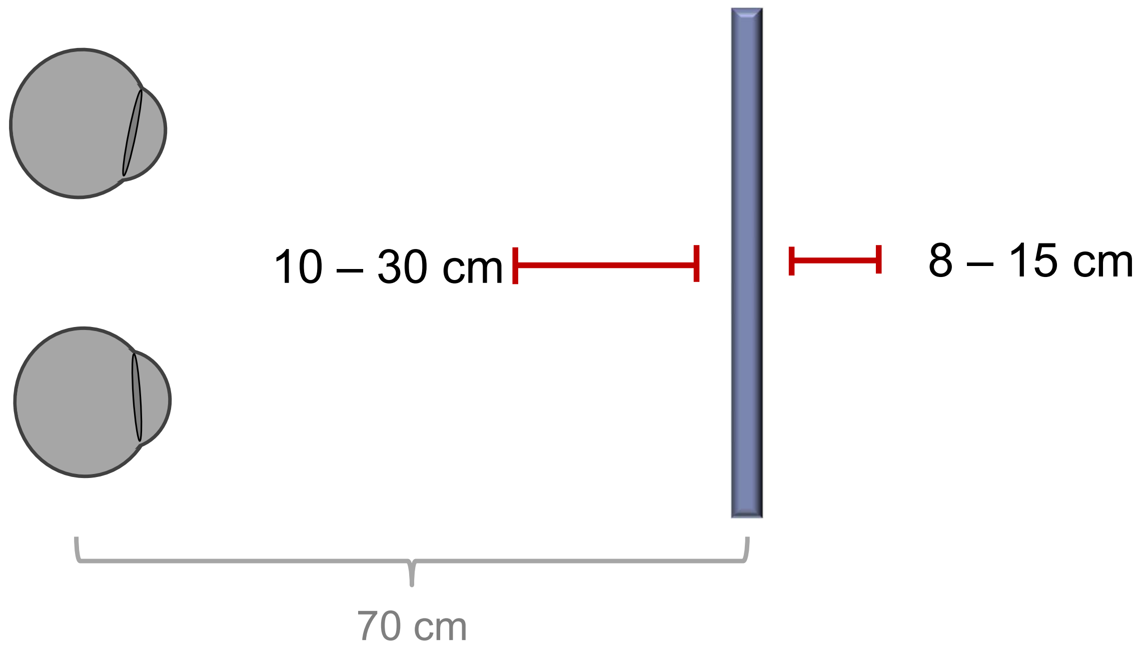
"Controlling Perceived Depth in Stereoscopic Images" by Jones et al. 2001

Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition

Difficult scene



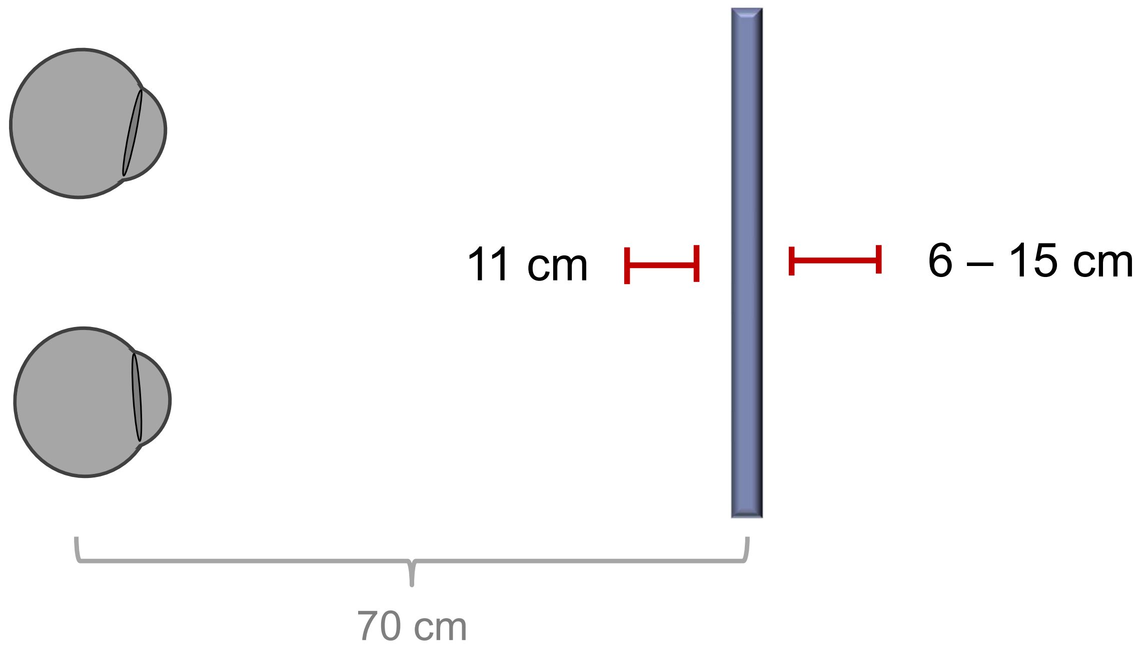
"Controlling Perceived Depth in Stereoscopic Images" by Jones et al. 2001

Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition

Difficult scene, user allowed to look away from screen



“Controlling Perceived Depth in Stereoscopic Images” by Jones et al. 2001

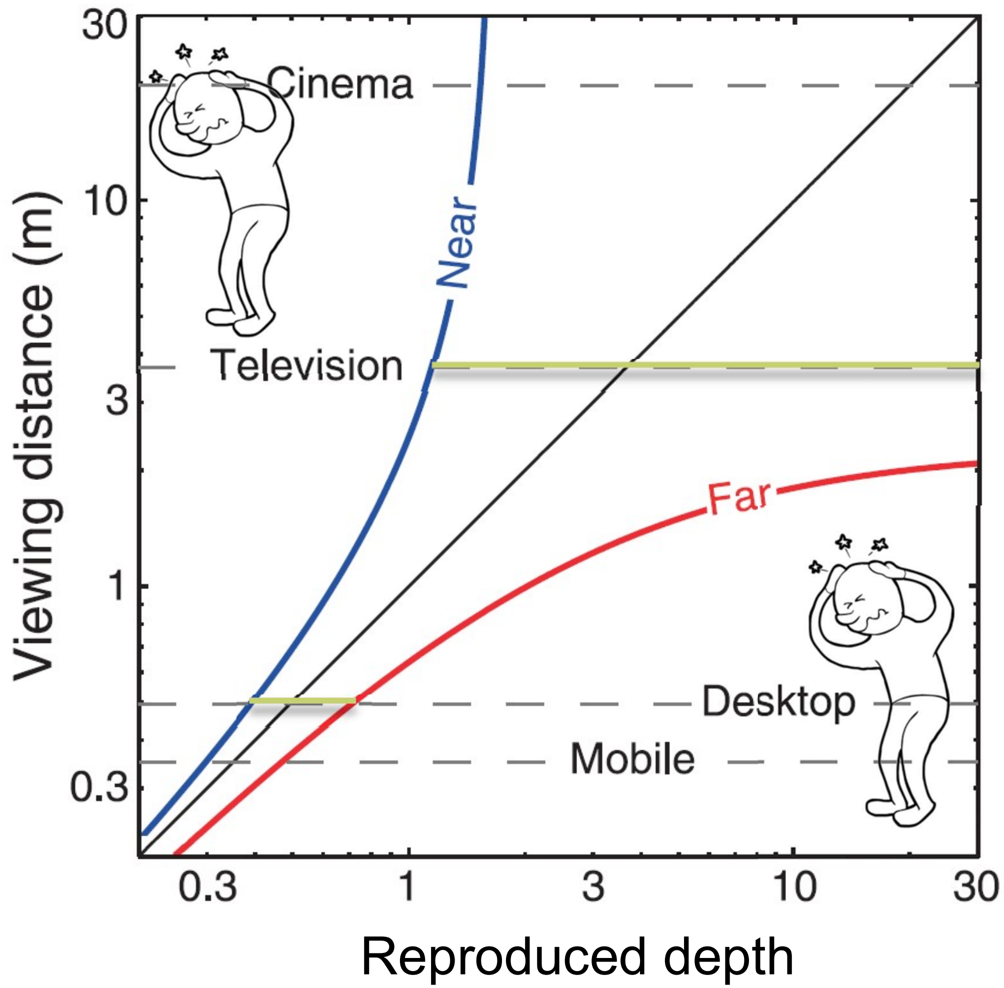
Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition
- Screen distance

Other factors:

- Distance between eyes
- Depth of field
- Temporal coherence



"The zone of comfort: Predicting visual discomfort with stereo displays" by Shibata et al. 2011

Depth manipulation

Advanced Graphics & Image Processing

Stereo Rendering

Part 2/3 – 3D display technologies

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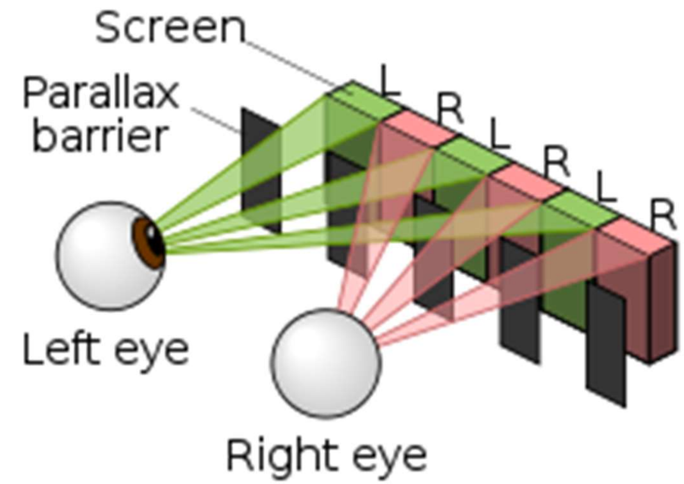
Stereoscopic displays

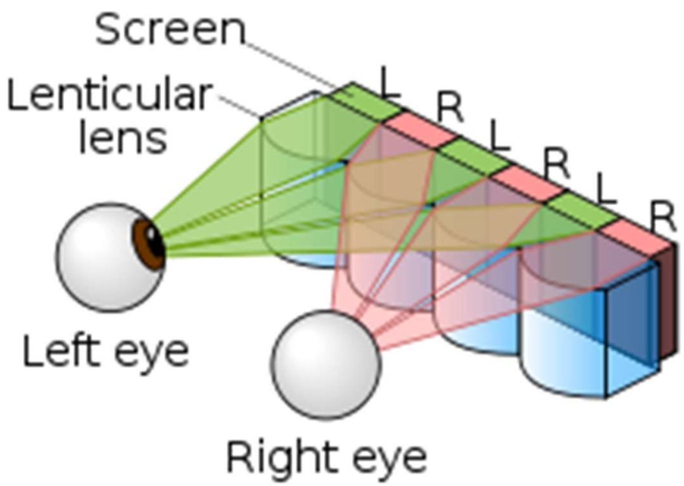


- Stereoscopic (with glasses)
  - Anaglyps (red & cyan glasses)
  - Shutter glasses: most TV sets
  - Circular polarization: RealD 3D cinema, 3D displays from LG
  - Interference filters: Dolby 3D cinema
- How do they work?
- Which method suffers from:
  - reduced brightness;
  - distorted colours;
  - cross-talk between the eyes;
  - cost (to manufacture)?


Stereoscopic displays

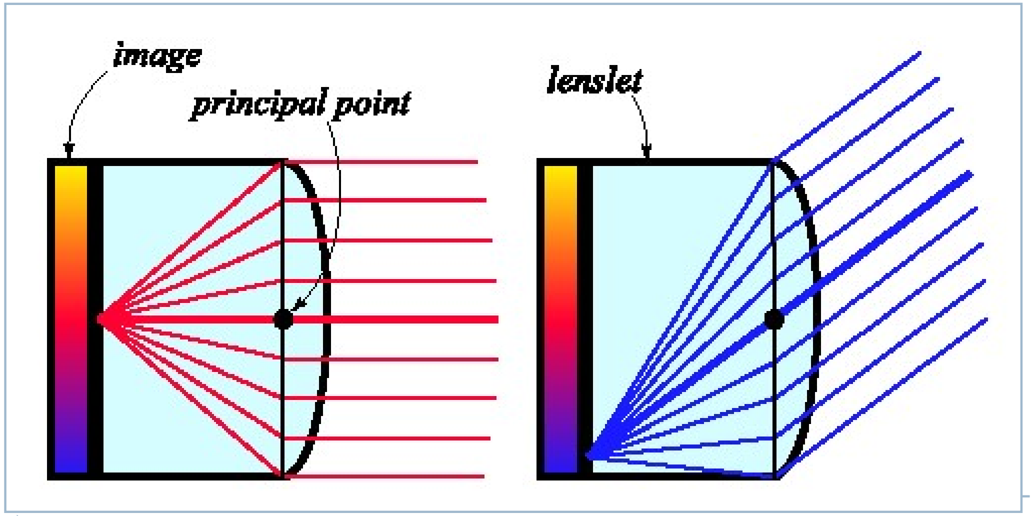
- Auto-stereoscopic (without glasses)
  - Parallax barrier
    - Example: Nintendo 3DS, some laptops and mobile phones
    - Switchable 2D/3D
  - Lenticular lens
    - Better efficiency
    - Non-switchable

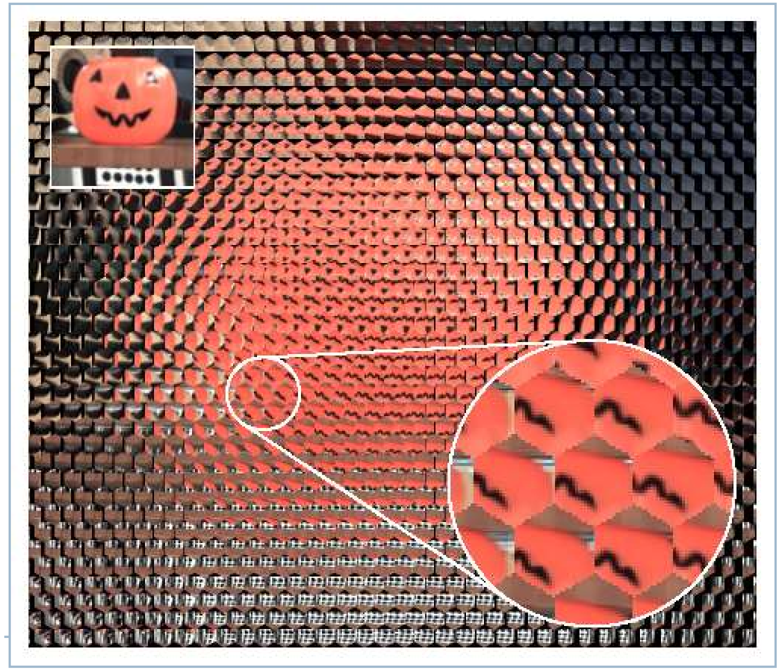




Light field Displays

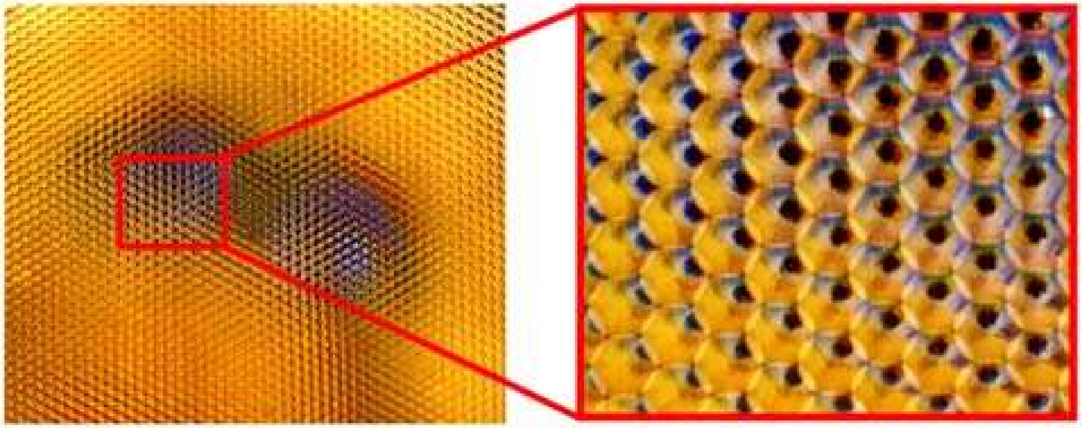
- integral photography, e. g. [Okano98]
- micro lens-array in front of screen
- screen at focal distance of micro lenses
  - → Parallel rays for each pixel
  - → Each eye sees a different pixel





Light field Displays

integral photograph close-up



one particular view

- need high resolution images
- taken with micro lens array
- screen is auto-stereoscopic

  → no glasses, multiple users

Advanced Graphics & Image Processing

Stereo Rendering

Part 3/3 – stereo rendering

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Put on Your 3D Glasses Now!

The slides used in this section are the courtesy of Gordon Wetzstein.
From Virtual Reality course: http://stanford.edu/class/ee267/

pintrest.com

Anaglyph Stereo - Monochrome

- render L & R images, convert to grayscale
- merge into red-cyan anaglyph by assigning I(r)=L, I(g,b)=R (I is anaglyph)

from movie “Bick Buck Bunny”

Anaglyph Stereo – Full Color

- render L & R images, do not convert to grayscale
- merge into red-cyan anaglyph by assigning I(r)=L(r), I(g,b)=R(g,b) (I is anaglyph)

from movie "Bick Buck Bunny"

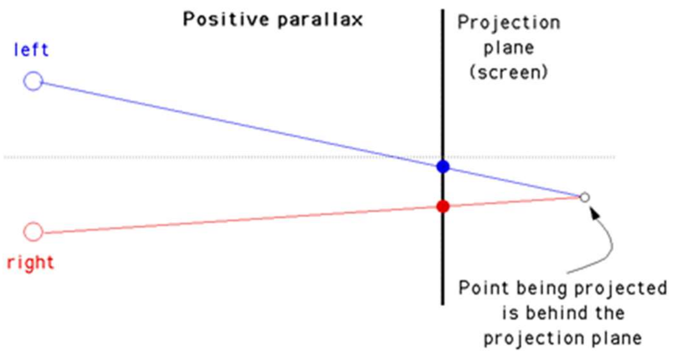
Open Source Movie: Big Buck Bunny

Rendered with Blender (Open Source 3D Modeling Program)

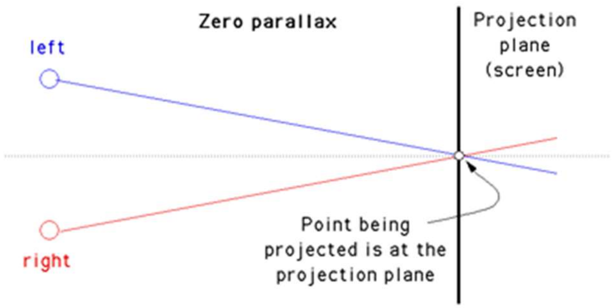
http://bbb3d.renderfarming.net/download.html

Parallax

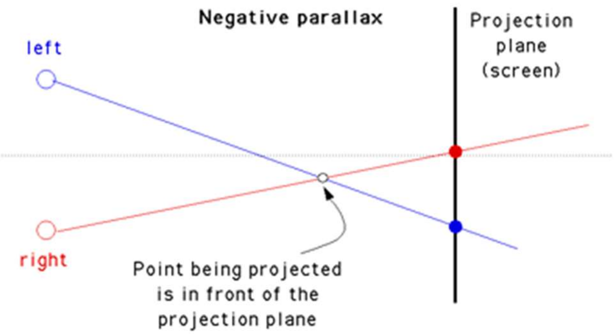
- Parallax is the relative distance of a 3D point projected into the 2 stereo images



case 1



case 2

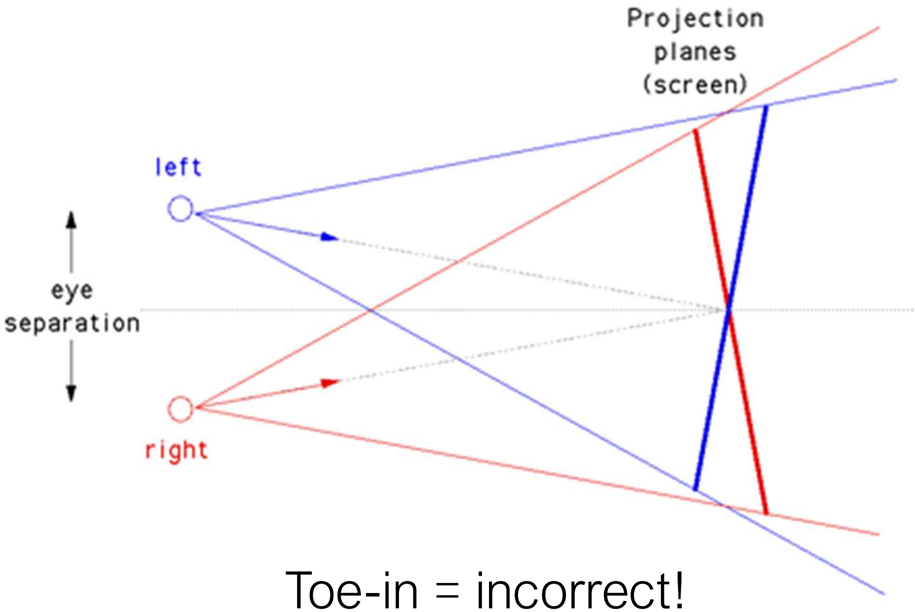


case 3

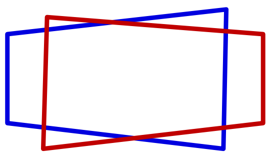
http://paulbourke.net/stereographics/stereorender/

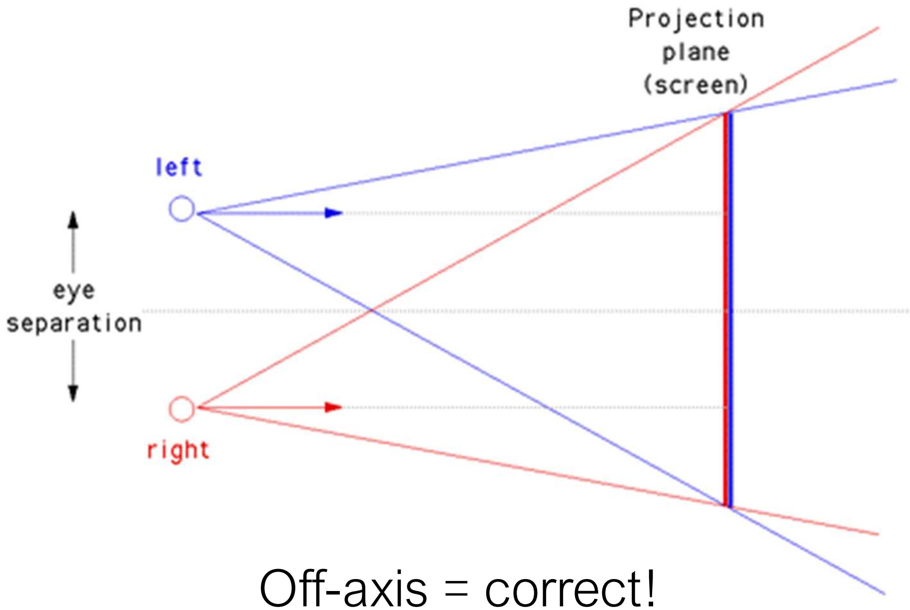
Parallax

- visual system only uses horizontal parallax, no vertical parallax!
- naïve toe-in method creates vertical parallax and visual discomfort



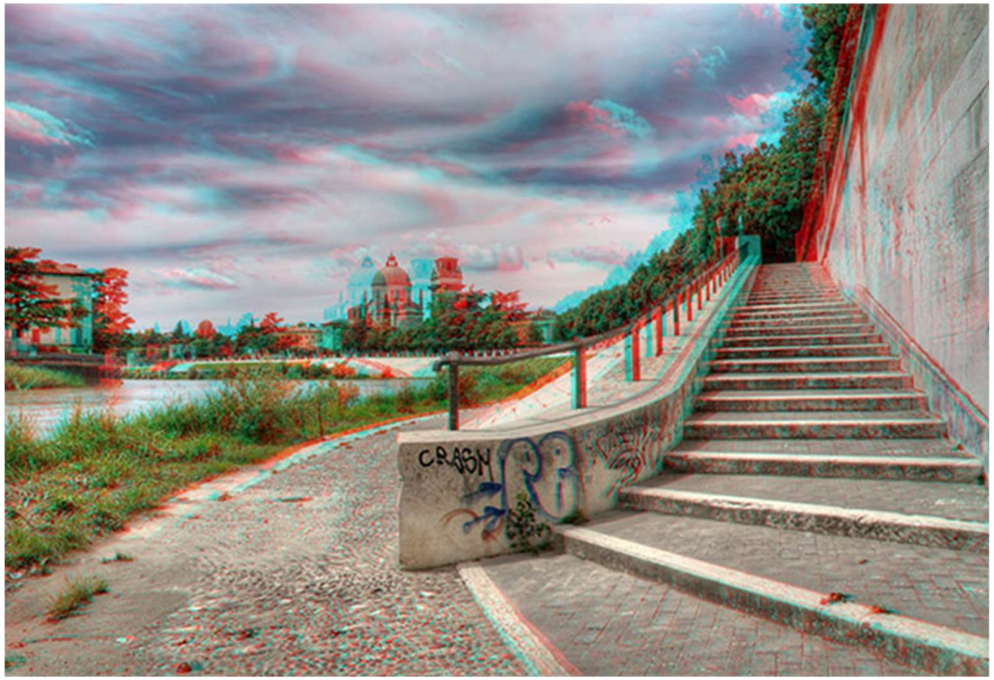
Toe-in = incorrect!



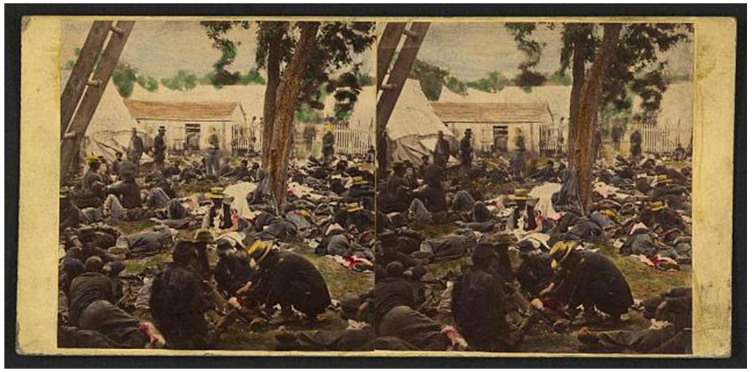


Off-axis = correct!

Parallax – well done



Parallax – well done



1862
“Tending wounded Union soldiers at Savage's Station, Virginia, during the Peninsular Campaign”,
Library of Congress Prints and Photographs Division

Parallax – not well done (vertical parallax = unnatural)

References

- LaValle "Virtual Reality", Cambridge University Press, 2016
  - Chapter 6
  - http://vr.cs.uiuc.edu/