



Stereo Rendering

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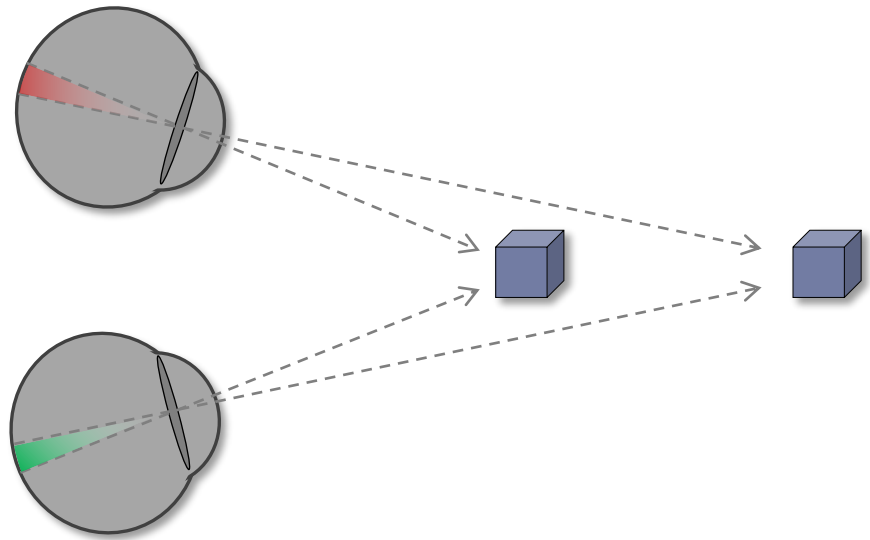
Overview

- ▶ Depth perception
- ▶ 3D display technologies
- ▶ Stereo rendering

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

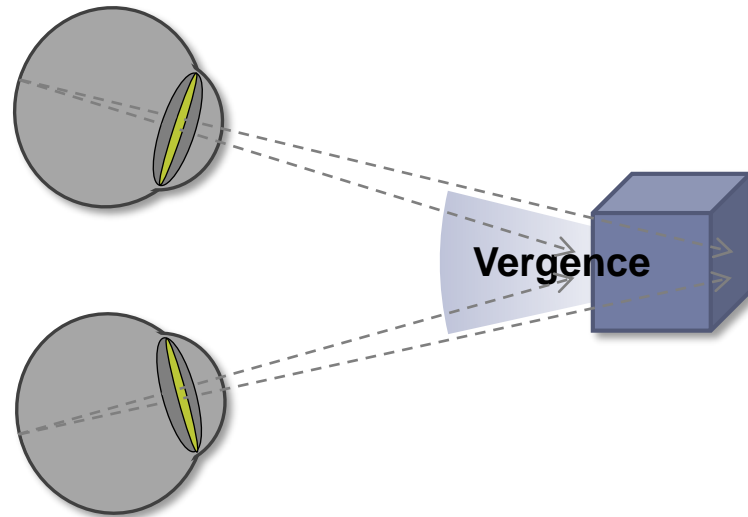
We see depth due to depth cues.

Stereoscopic depth cues:

binocular disparity

Ocular depth cues:

accommodation, vergence



Depth perception

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Stereoscopic depth cues:

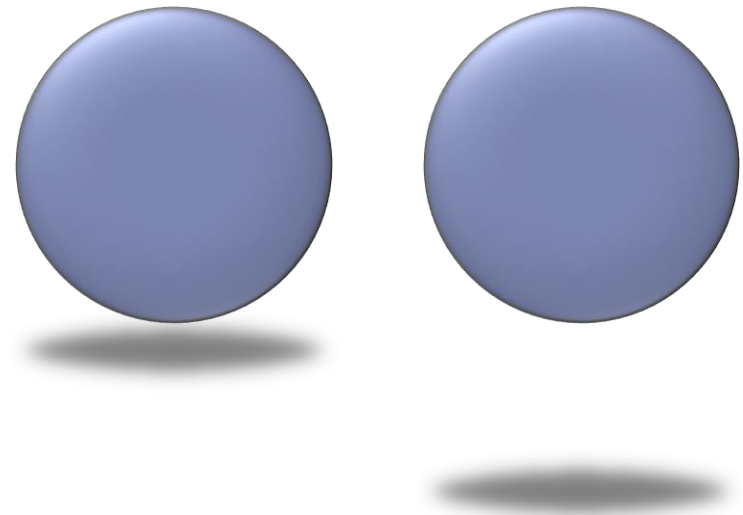
binocular disparity

Ocular depth cues:

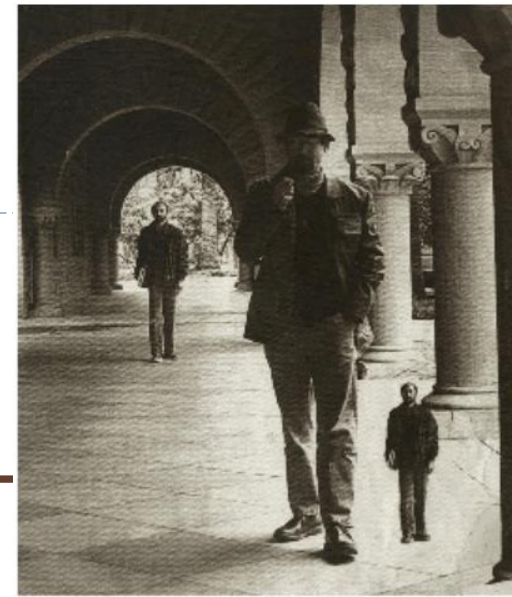
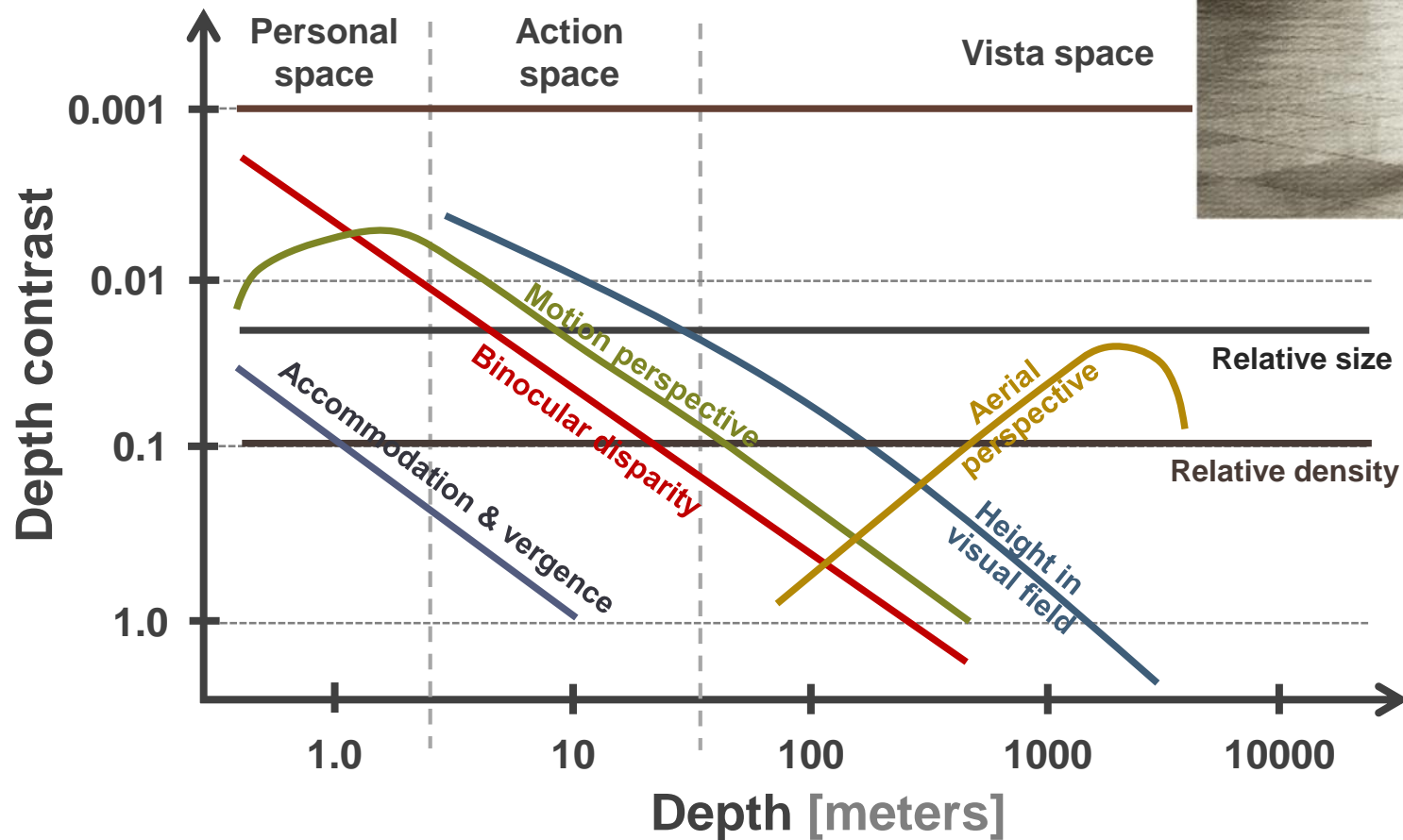
accommodation, vergence

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]

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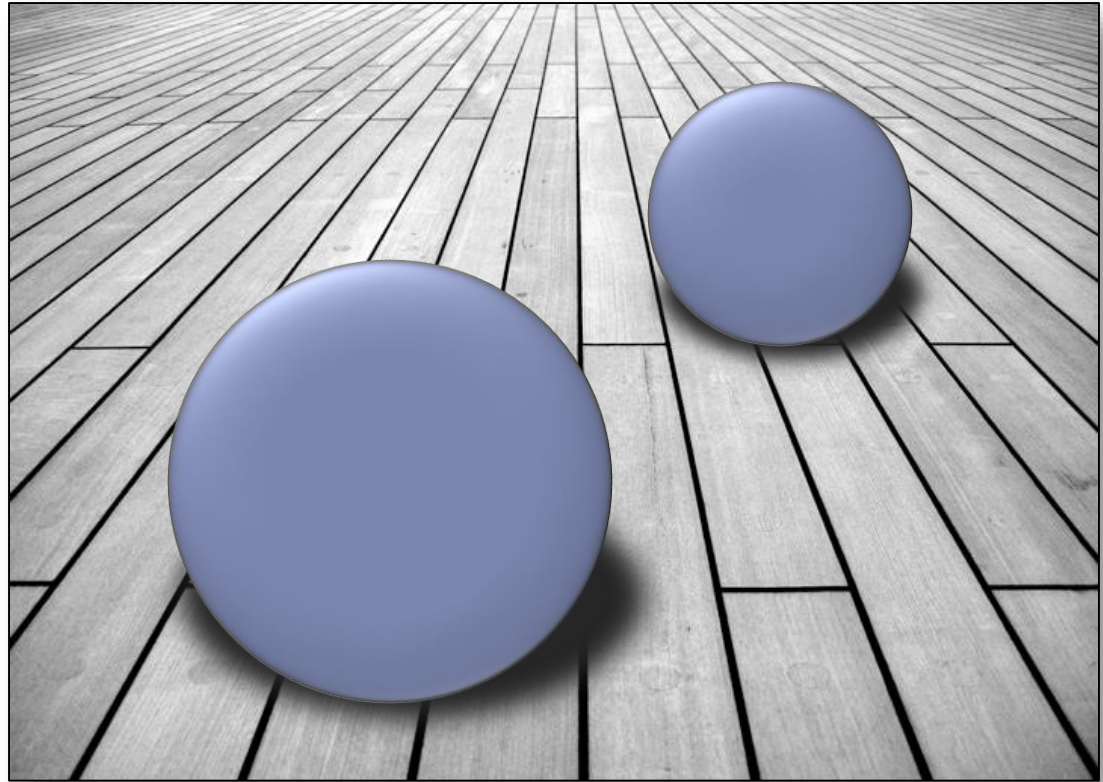
Challenge:
Consistency is
required!



Simple conflict example

Present cues:

- Size
- Shadows
- Perspective
- **Occlusion**



Disparity & occlusion conflict

Objects in front



Disparity & occlusion conflict

**Disparity & occlusion
conflict**



Depth perception

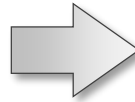
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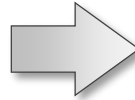


Require 3D space

We cheat our Visual System!

Pictorial depth cues:

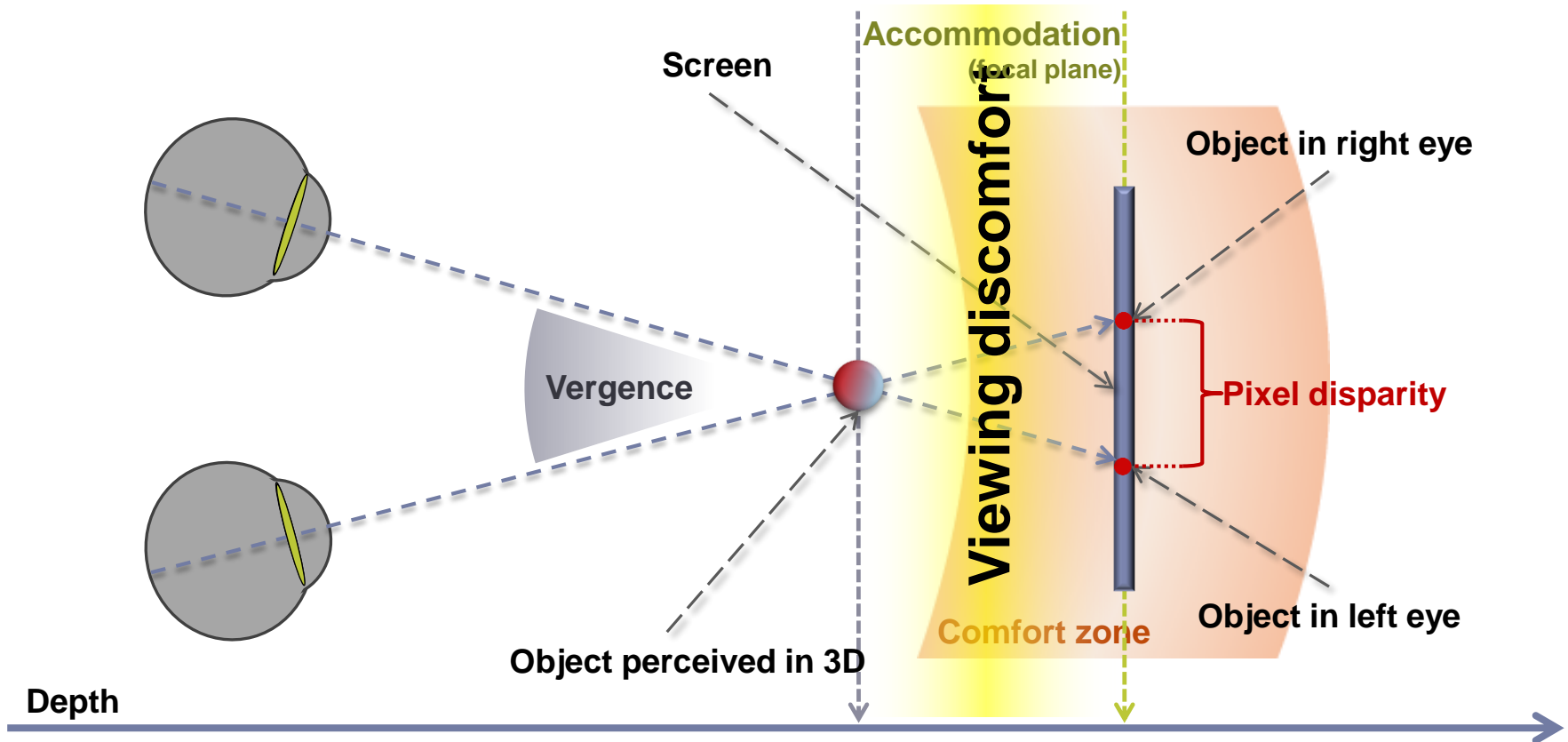
occlusion, size, shadows...



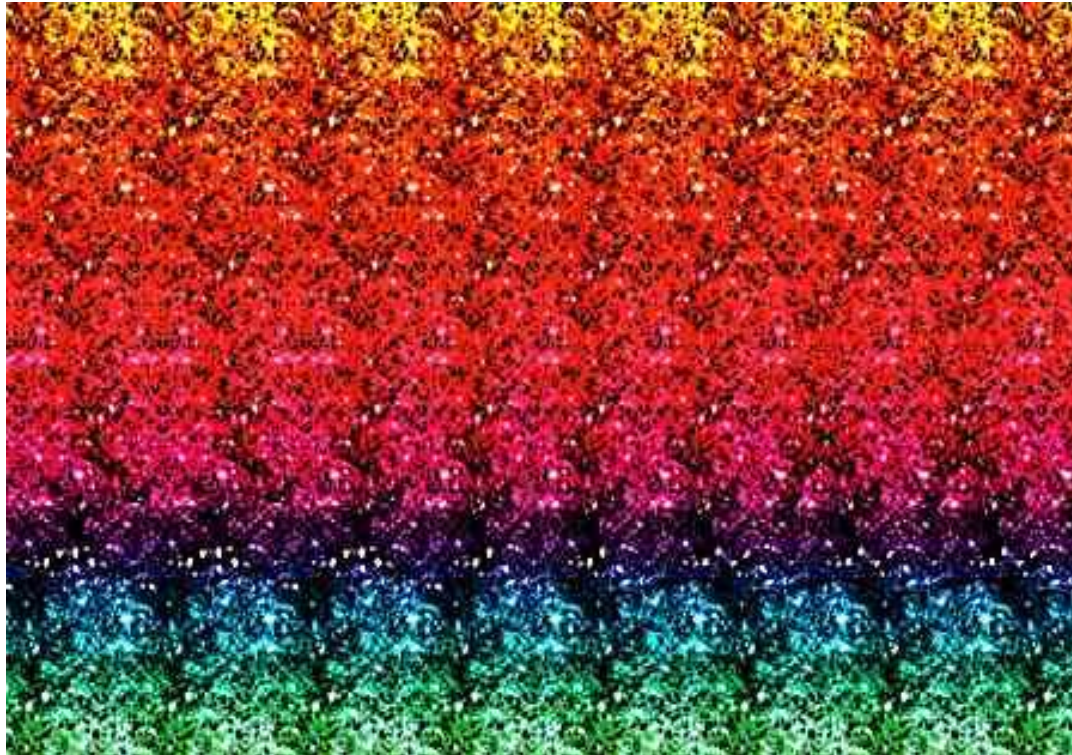
Reproducible on a flat displays



Cheating our HVS

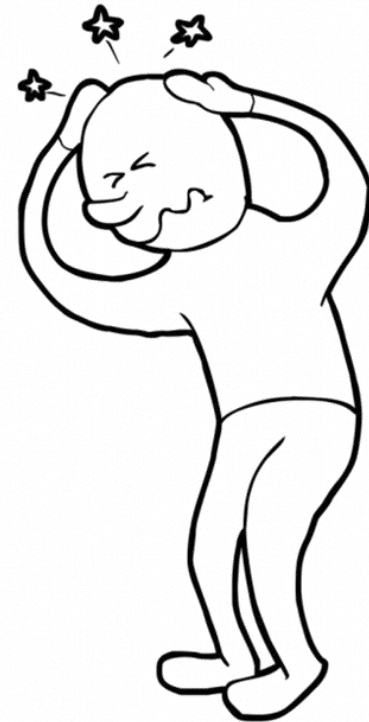


Single Image Random Dot Stereograms



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

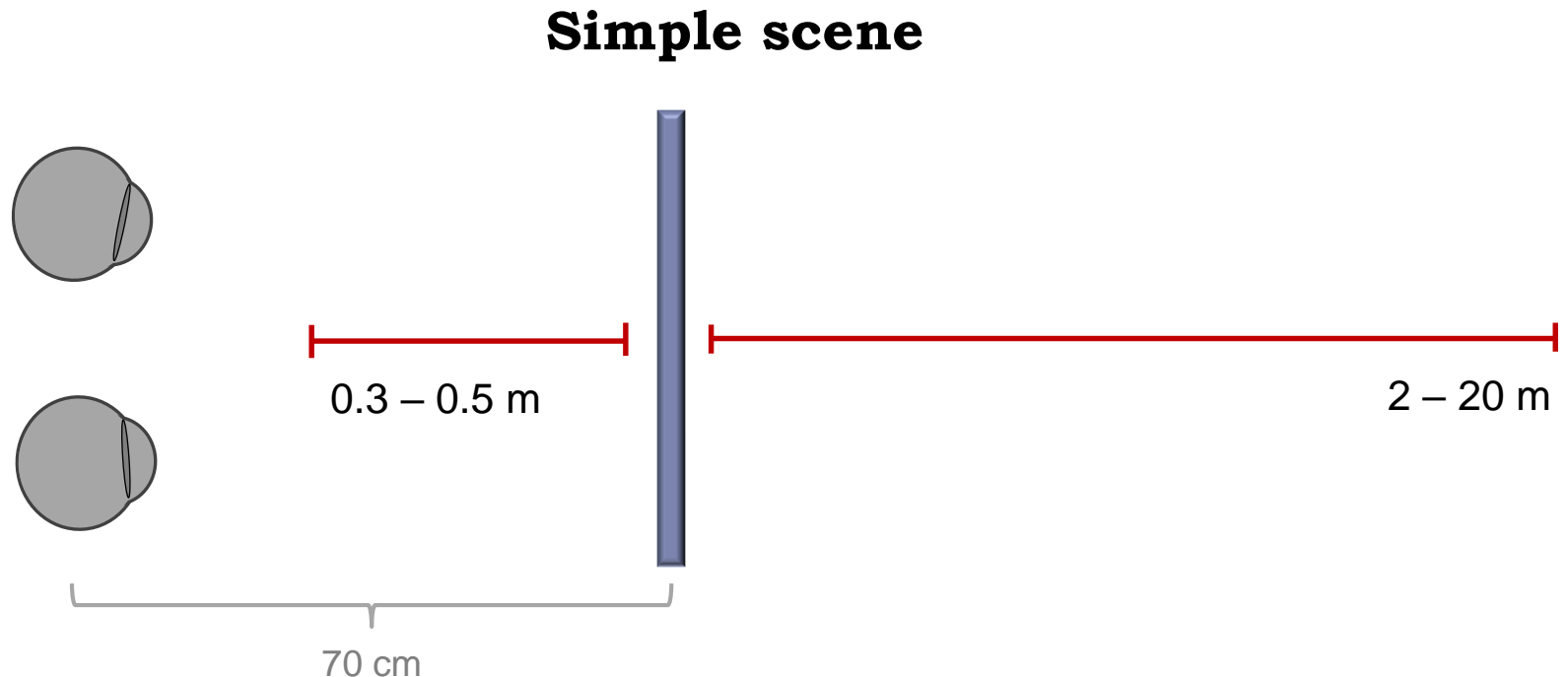
Viewing discomfort



Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition



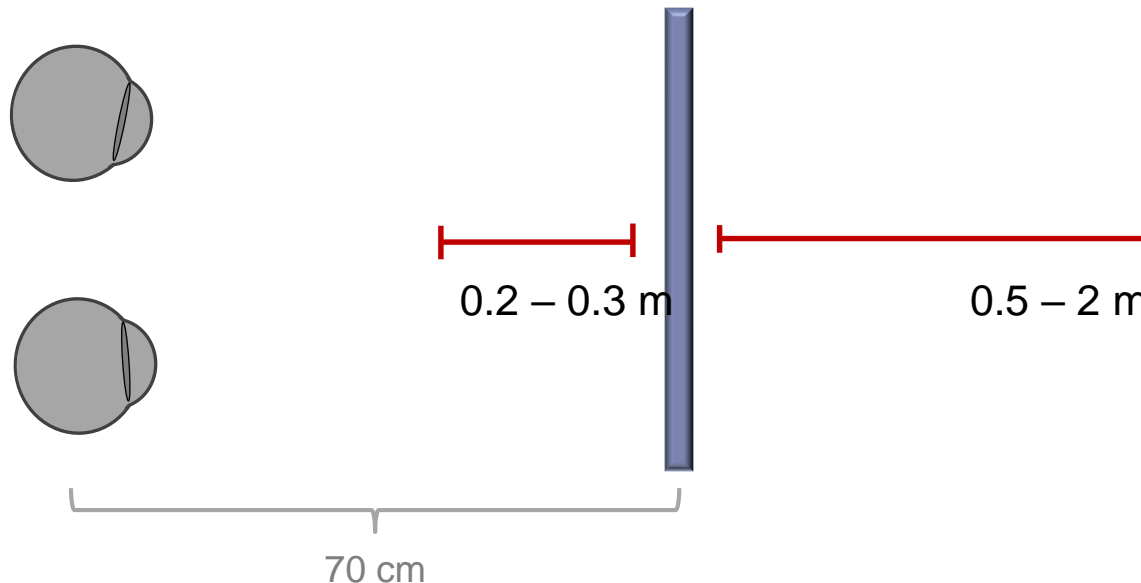
"Controlling Perceived Depth in Stereoscopic Images" by Jones et al. 2001

Comfort zones

Comfort zone size depends on:

- Presented content
- Viewing condition

Simple scene, user allowed to look away from screen



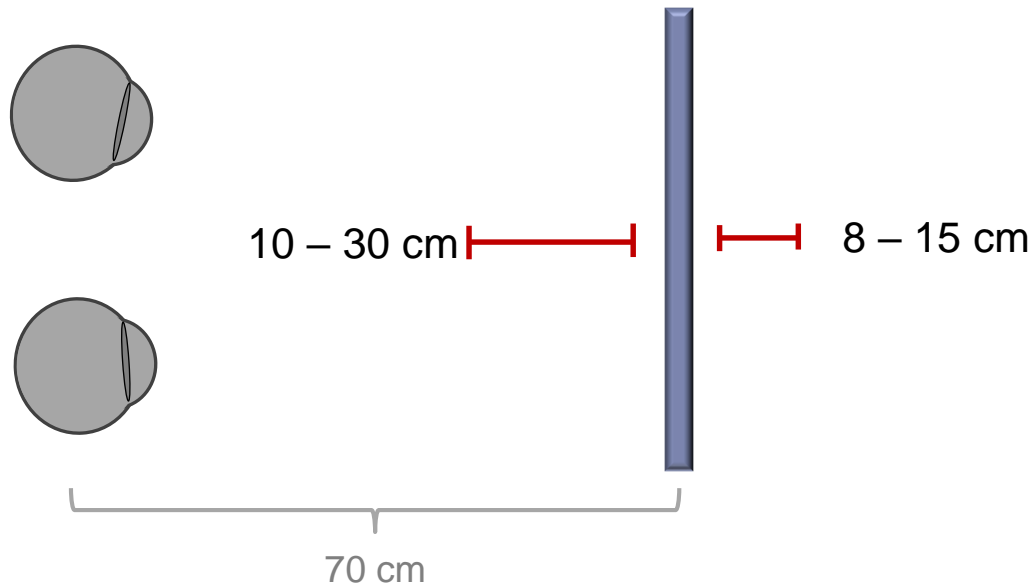
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Comfort zones

Comfort zone size depends on:

- Presented content
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Difficult scene



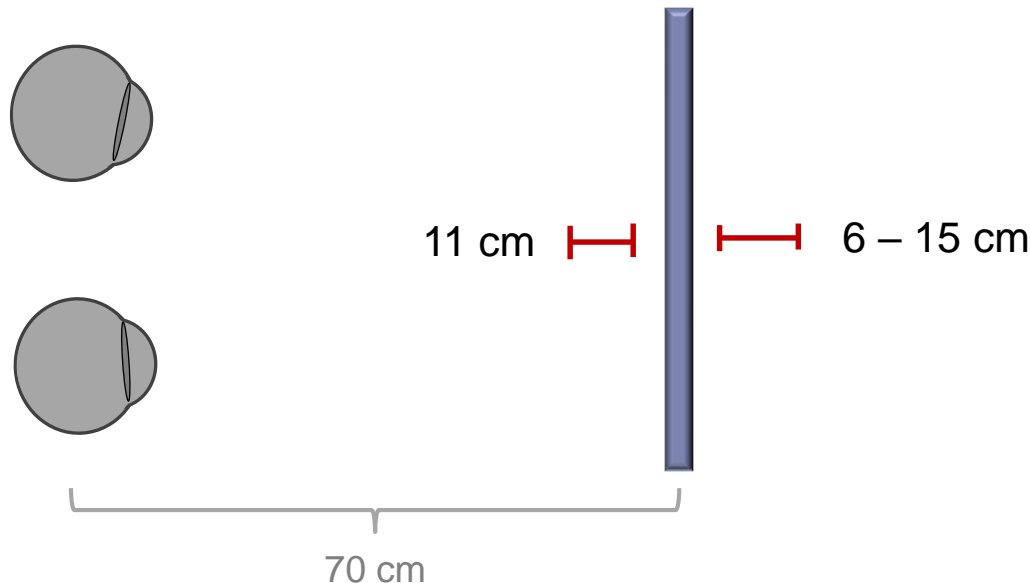
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Comfort zones

Comfort zone size depends on:

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Difficult scene, user allowed to look away from screen



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

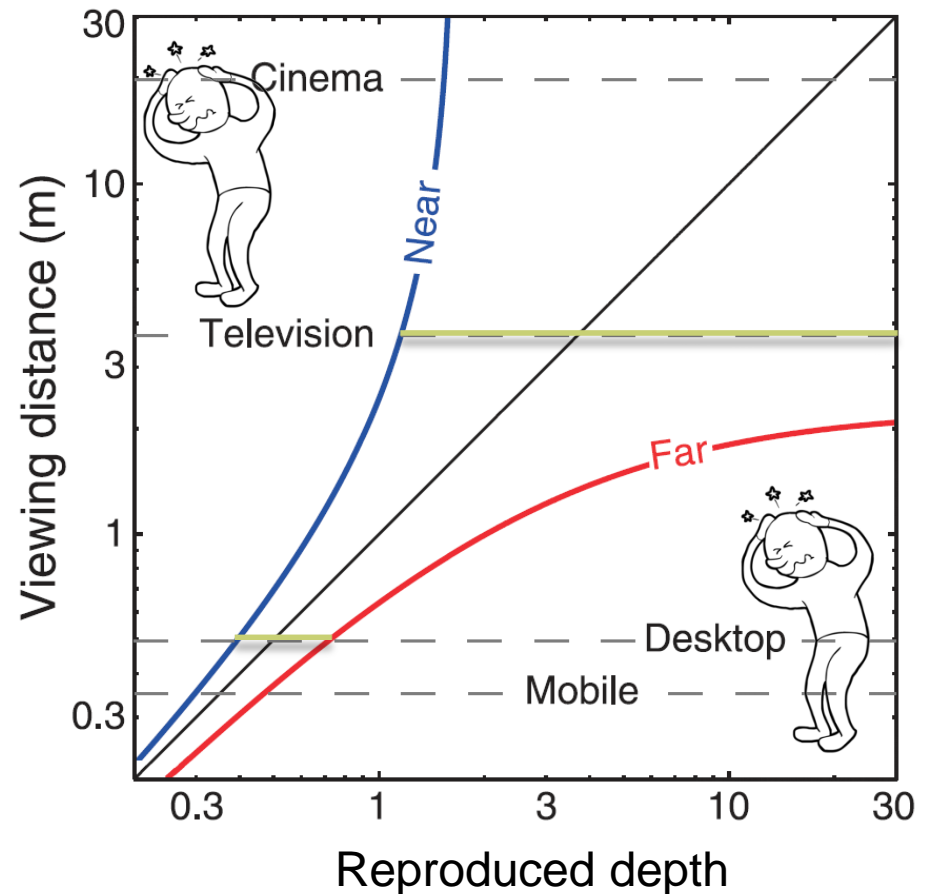
Comfort zones

Comfort zone size depends on:

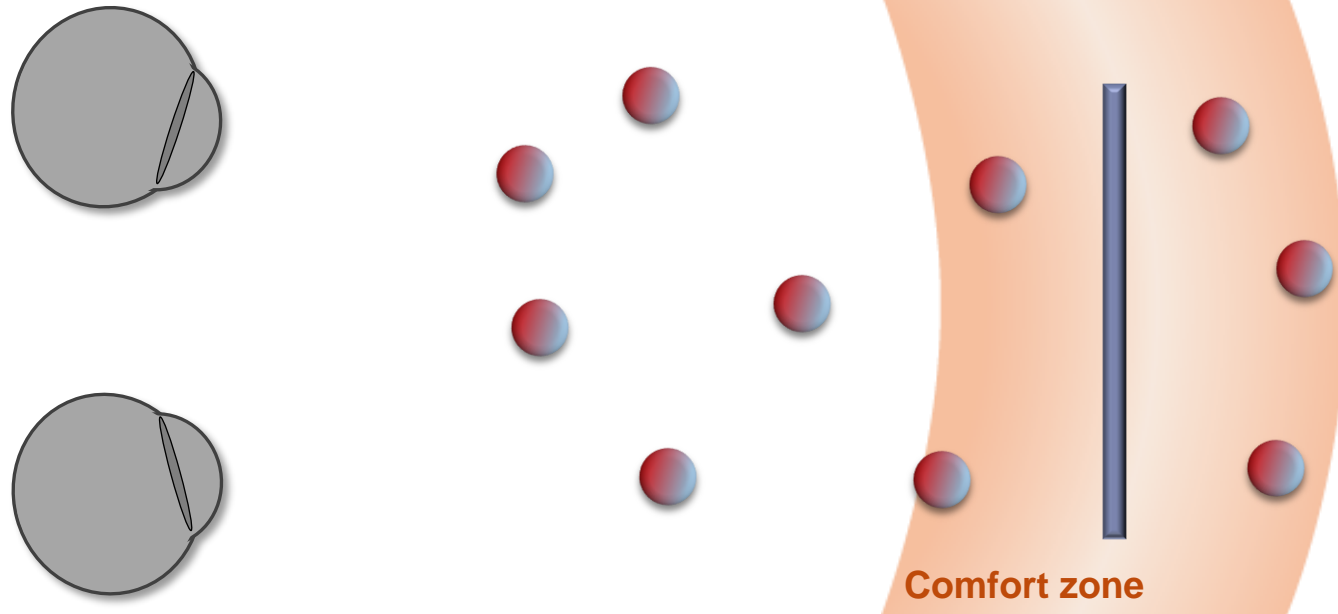
- Presented content
- Viewing condition
- Screen distance

Other factors:

- Distance between eyes
- Depth of field
- Temporal coherence



Depth manipulation



Viewing discomfort Scene manipulation → **Viewing comfort**



Stereoscopic displays

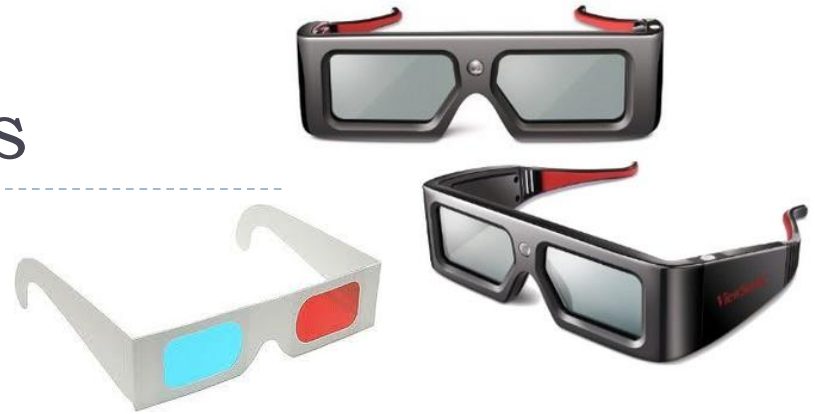
- ▶ Stereoscopic (with glasses)

- ▶ Anaglyphs (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

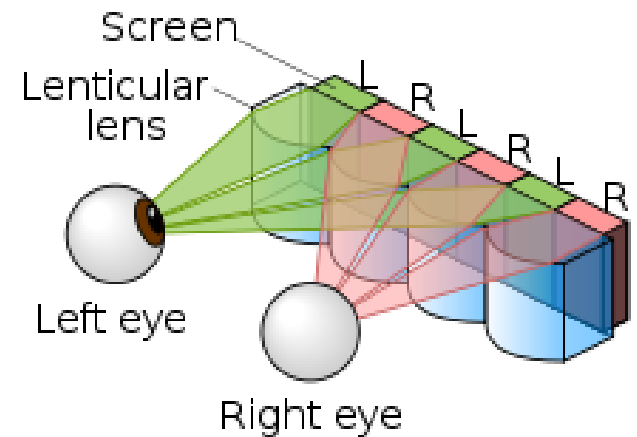
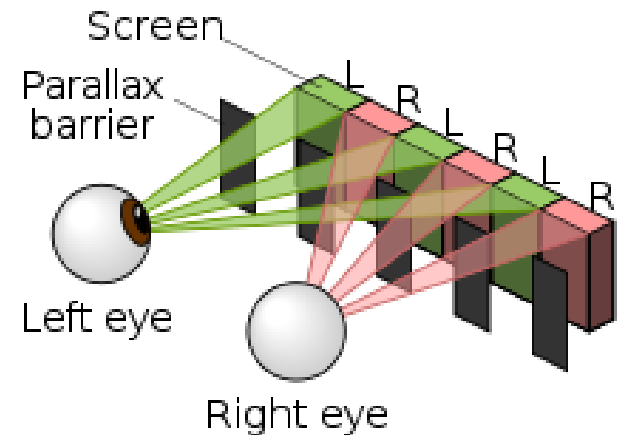
▶ Auto-stereoscopic (without glasses)

▶ Parallax barrier

- ▶ Example: Nintendo 3DS, some laptops and mobile phones
- ▶ Switchable 2D/3D

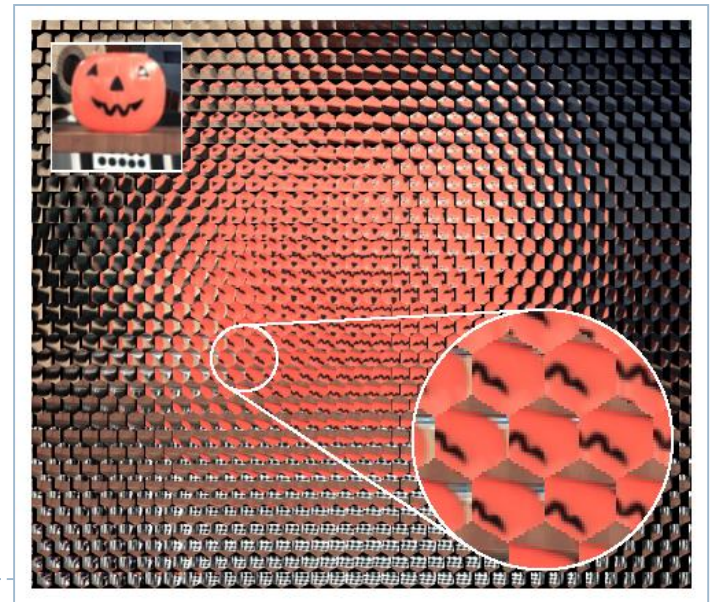
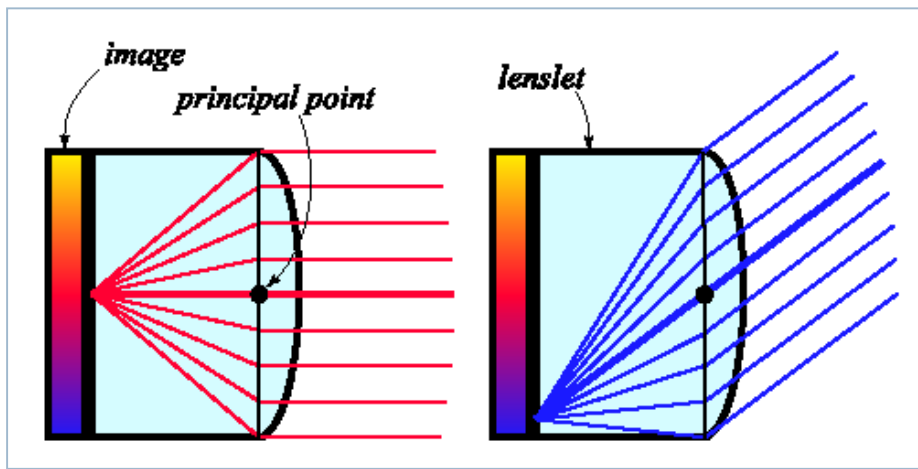
▶ Lenticular lens

- ▶ 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
 - every eye sees a different pixel

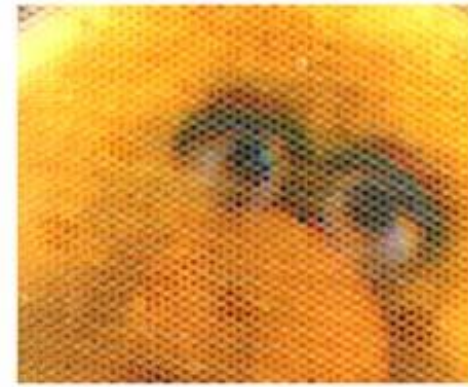
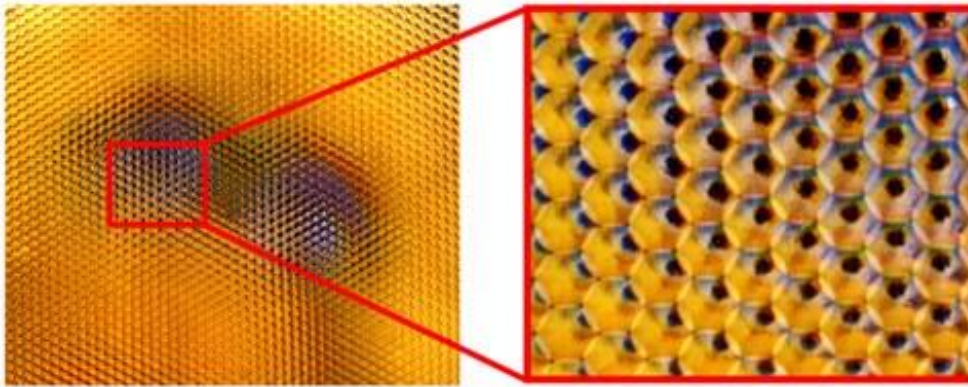


Light field Displays

integral photograph

close-up

one particular view



- ❑ need high resolution images
- ❑ taken with micro lens array
- ❑ screen is auto-stereoscopic
 - no glasses, multiple users





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/>



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 "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)

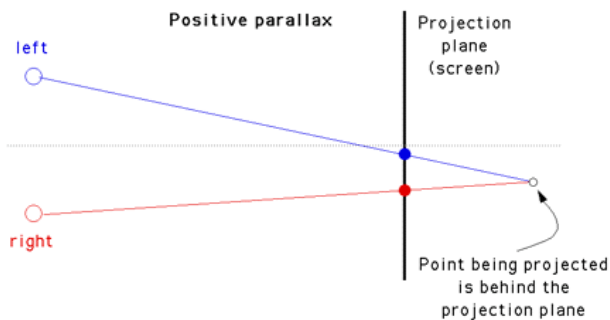
<http://bbb3d.renderfarming.net/download.html>



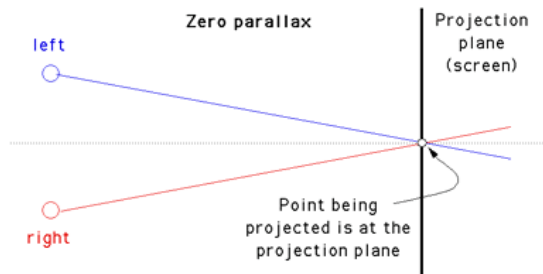


Parallax

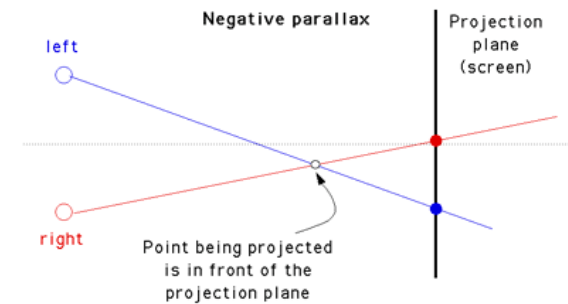
- ▶ Parallax is the relative distance of a 3D point projected into the 2 stereo images



case 1



case 2

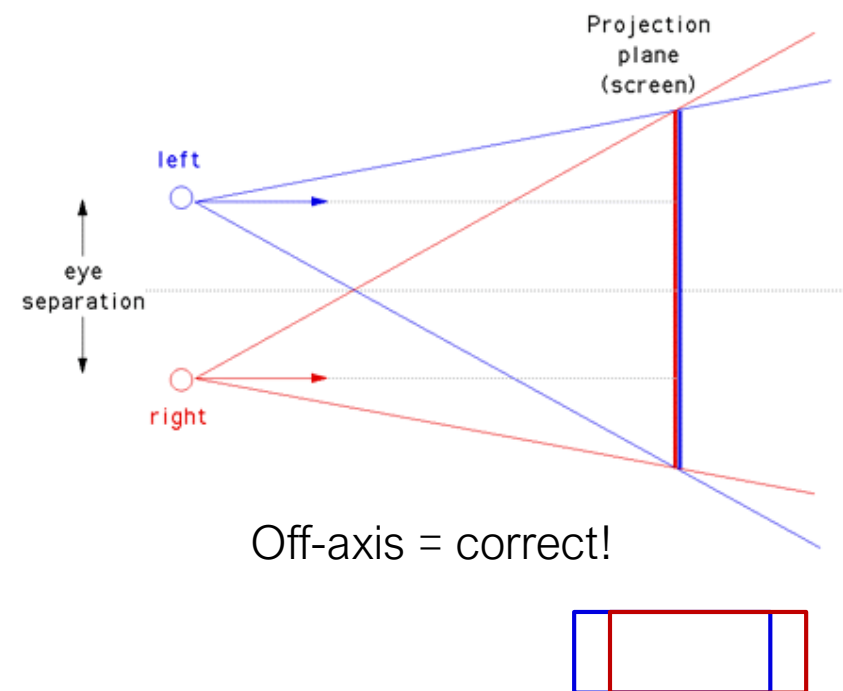
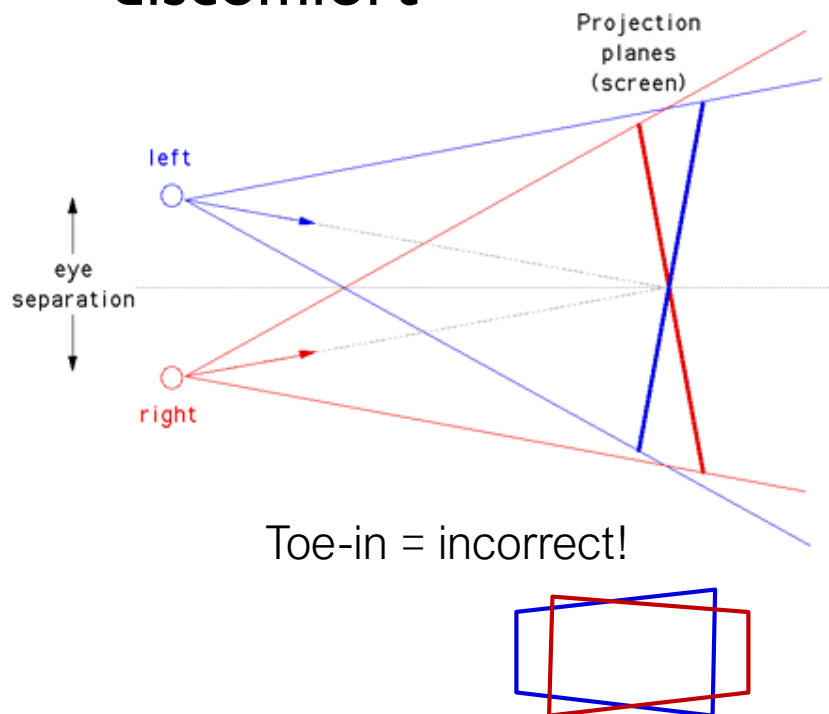


case 3

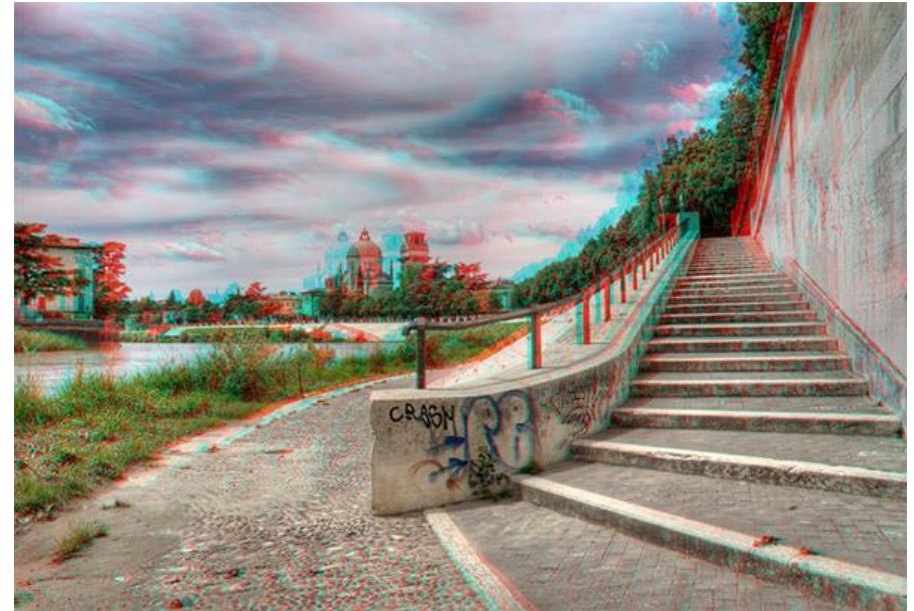


Parallax

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



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/>