Stereoscopy and Depth Perception

EPFL Immersive Interaction Group

Based on Dr Nan Wang course

Outline

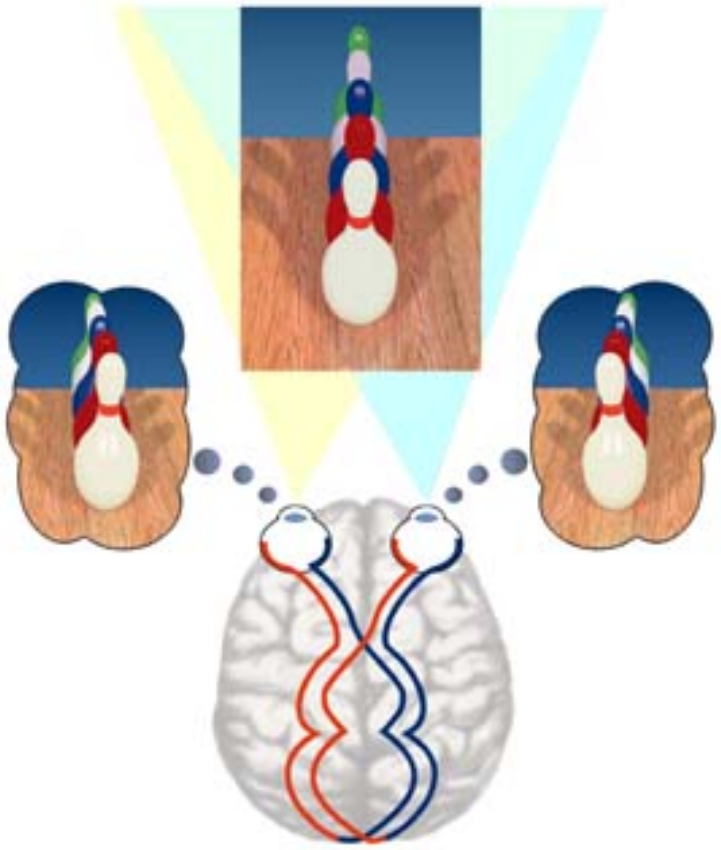
- Stereoscopic vision (stereopsis)
- Understanding depth
- Depth cues effectiveness
- Overview of stereoscopic delivery
- Conclusion

Stereoscopic vision (stereopsis)

- Principle identified by C. Wheathstone (1838)

2 Views Fused in the Brain = Stereovision

- Each eye captures its own field of view
- The two eye field of views are recombined (in the *optic chiasm*) into a right and a left visual field
- The right visual field (red pathways) is sent to the left brain hemisphere, and vice-versa.
- The small differences between the left and right source of the visual signals add up to a big difference (Depth information)

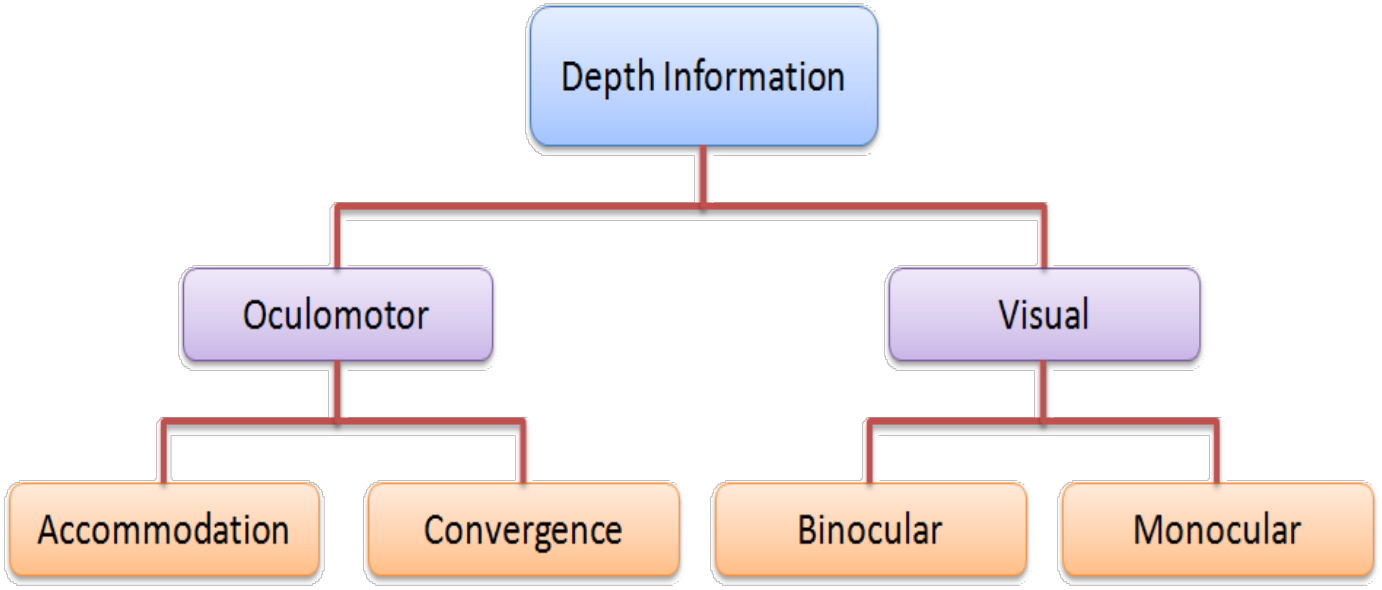


Stereoscopic vision

- Advantage of stereoscopic vision
  - Offer depth information -> moving toward or away from viewing point
  - In VR, provide the depth information by displaying different images for the right and the left eyes, matching the user's parameters.

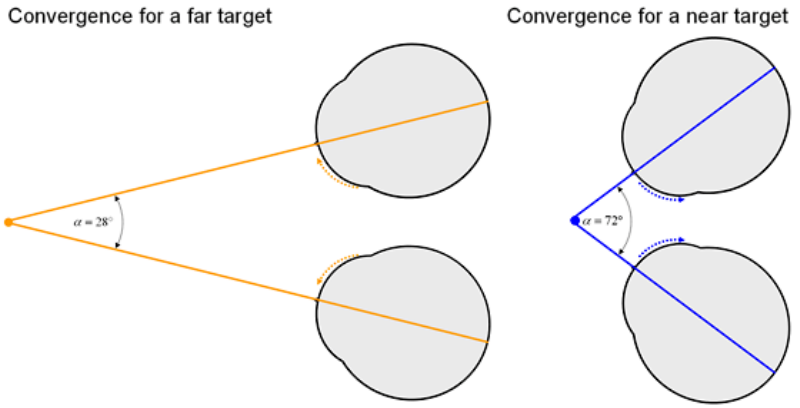
Understanding depth

- Depth information perception:
  - Oculomotor cues: Convergence and Accommodation
  - Visual cues: Monocular and Binocular

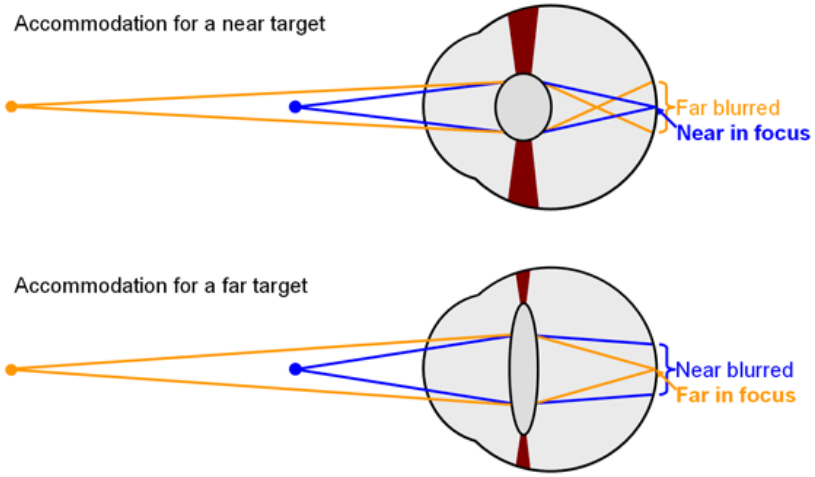


Oculomotor cues

- **Convergence**: the angle formed by your eyes and the observed object. The higher the angle value is, the nearer the observed object is to your two eyes, and vice versa.



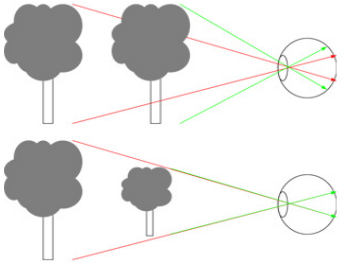
- **Accommodation**: process of changing optical power to maintain a clear image (focus) on an object as its distance varies.



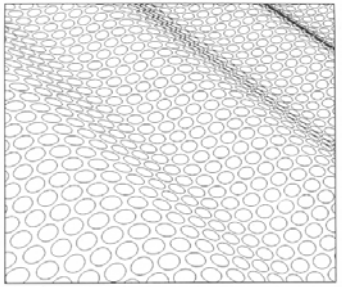
Accommodation and convergence allow us to see objects clearly both near and far without diplopia (double vision)

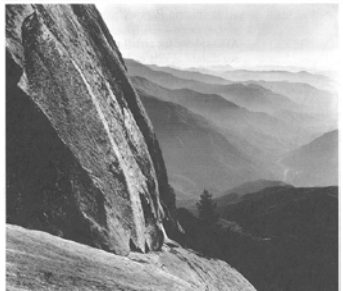
Visual cues / monocular

– Monocular cues :
  - Linear perspective
  - Relative Size
  - Texture Gradient
  - Occlusion
  - Shading
  - Tilt-shift
  - Motion Parallax
  - Atmospheric blur



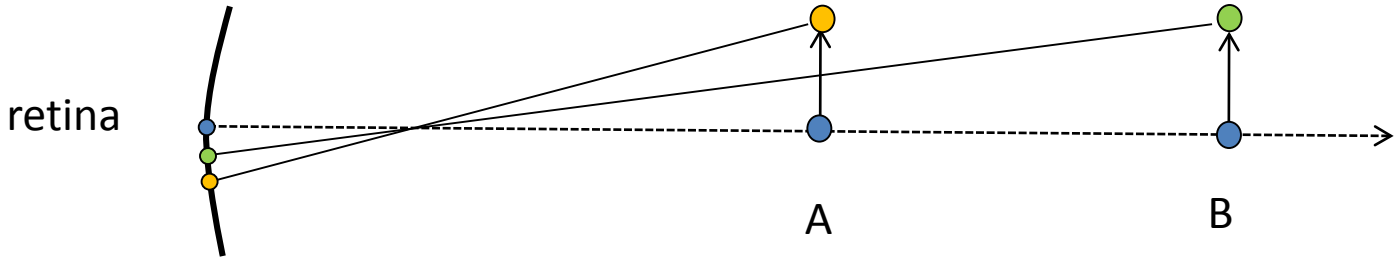


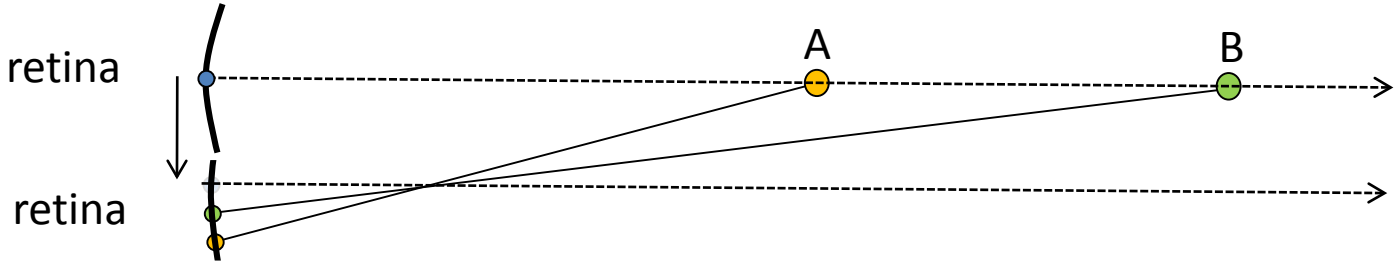
Visual cues / monocular (2)

Motion Parallax :

- for 2 entities with the same size, located at different depths and moving perpendicularly to the view axis , the closer one moves more on the retina than distant one.



- Conversely, moving the eye in front of static entities leads to a larger movement on the retina for the closest one.

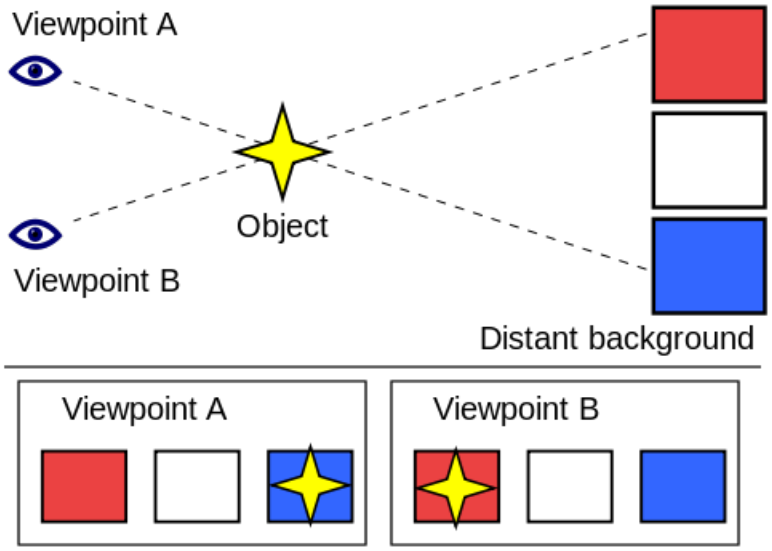


-> cheap and powerful means for providing depth cues

Binocular depth visual cues

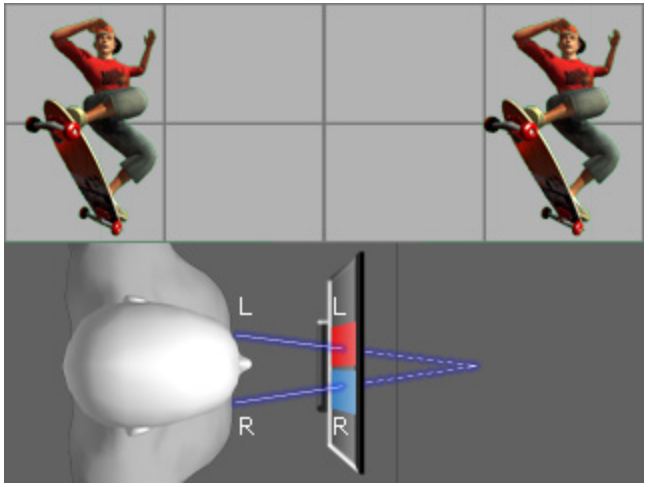
Parallax :

- is a displacement or difference in the apparent position of an object viewed along two different lines of sight

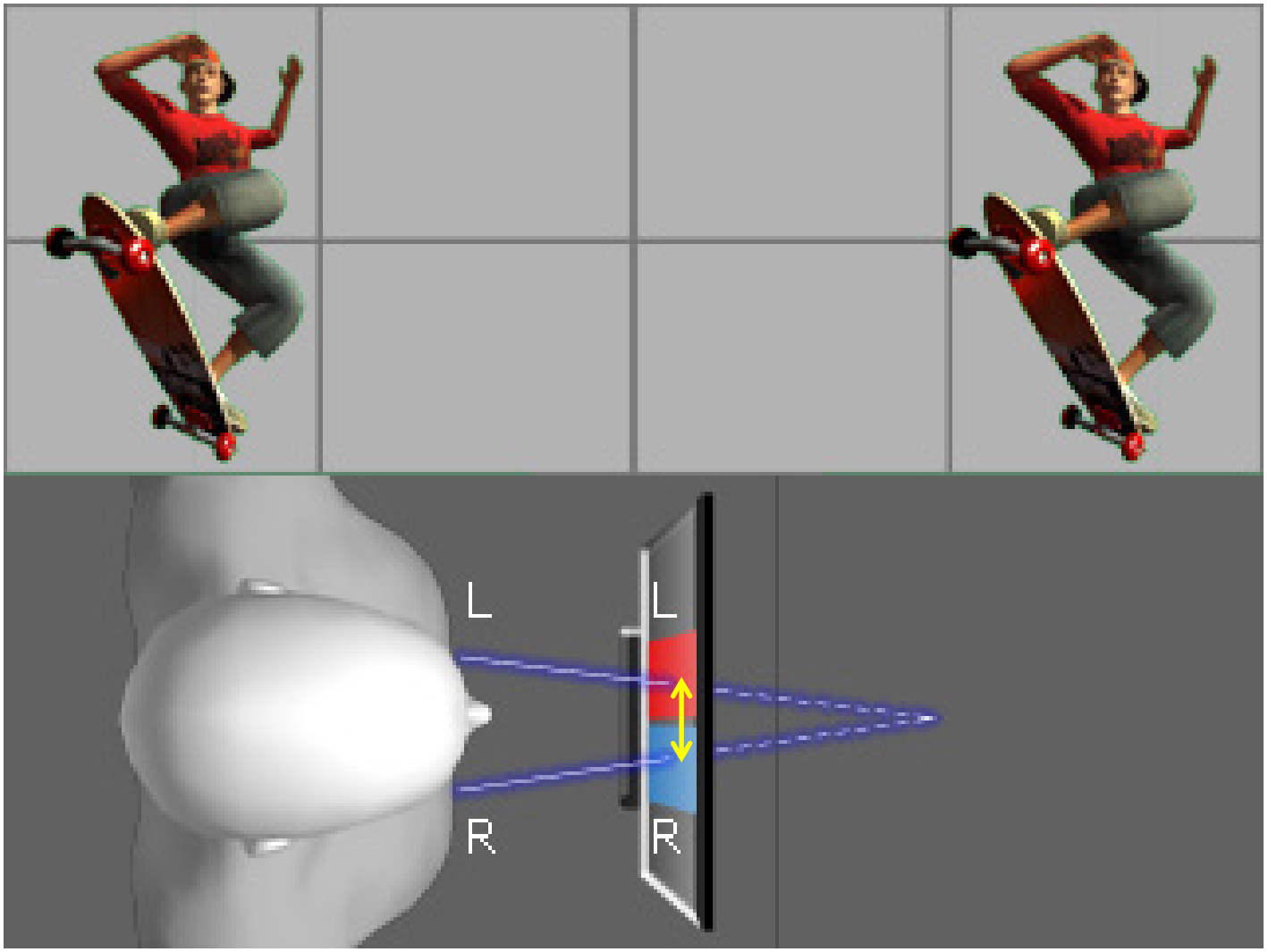


Positive parallax

- 3 types of parallax (1:3):
  - **Positive parallax**: The projection for the left eye is on the left and the projection for the right eye is on the right, the distance between the left and right eye projections is called the **horizontal parallax**



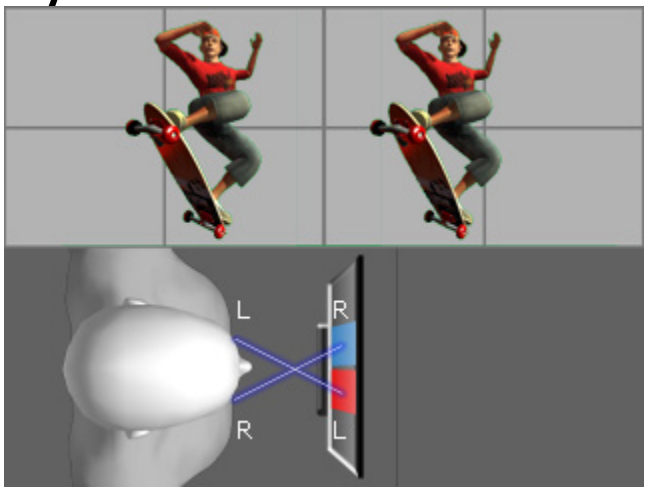
Your convergence point is lead to fall behind the display.

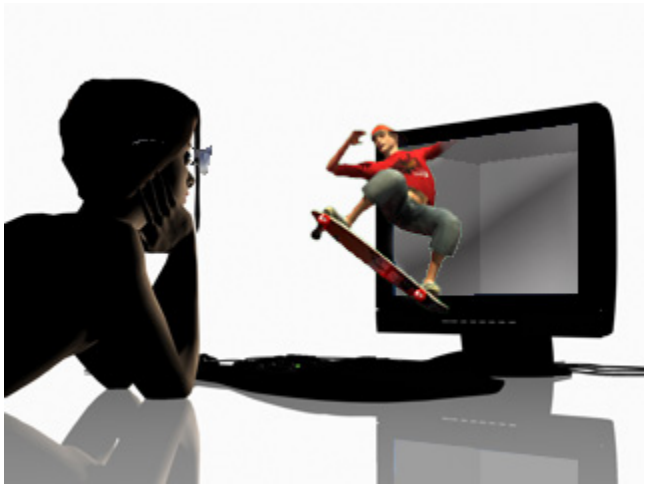


Your convergence point is lead to fall behind the display.

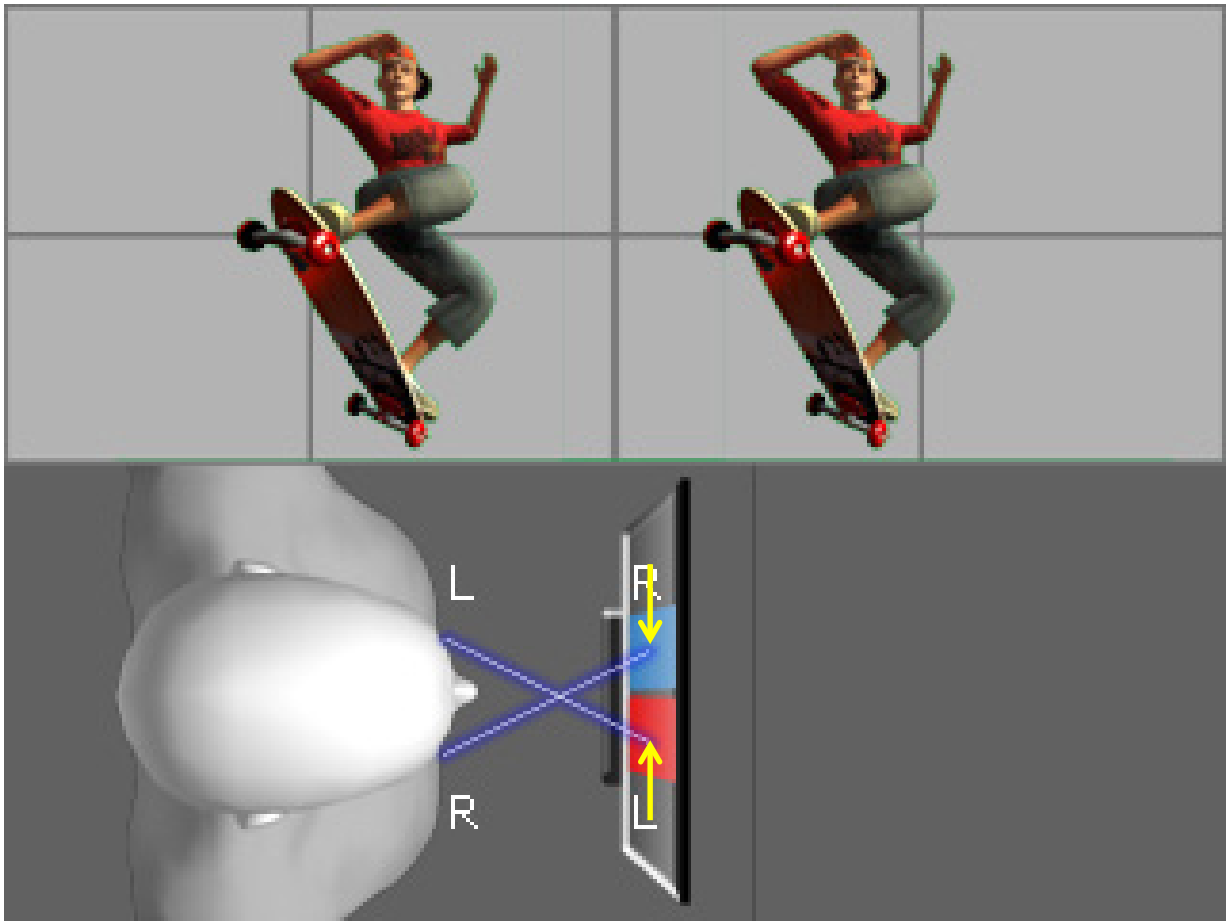
Negative parallax

- 3 types of parallax (2:3):
  - **Negative parallax**: If an object is located in front of the projection plane then the projection for the left eye is on the right and the projection for the right eye is on the left.





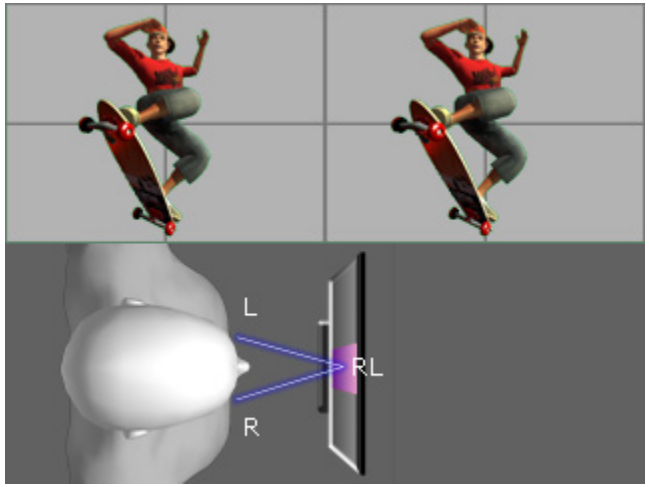
The L and R images lead your convergence point to fall in front of the display.



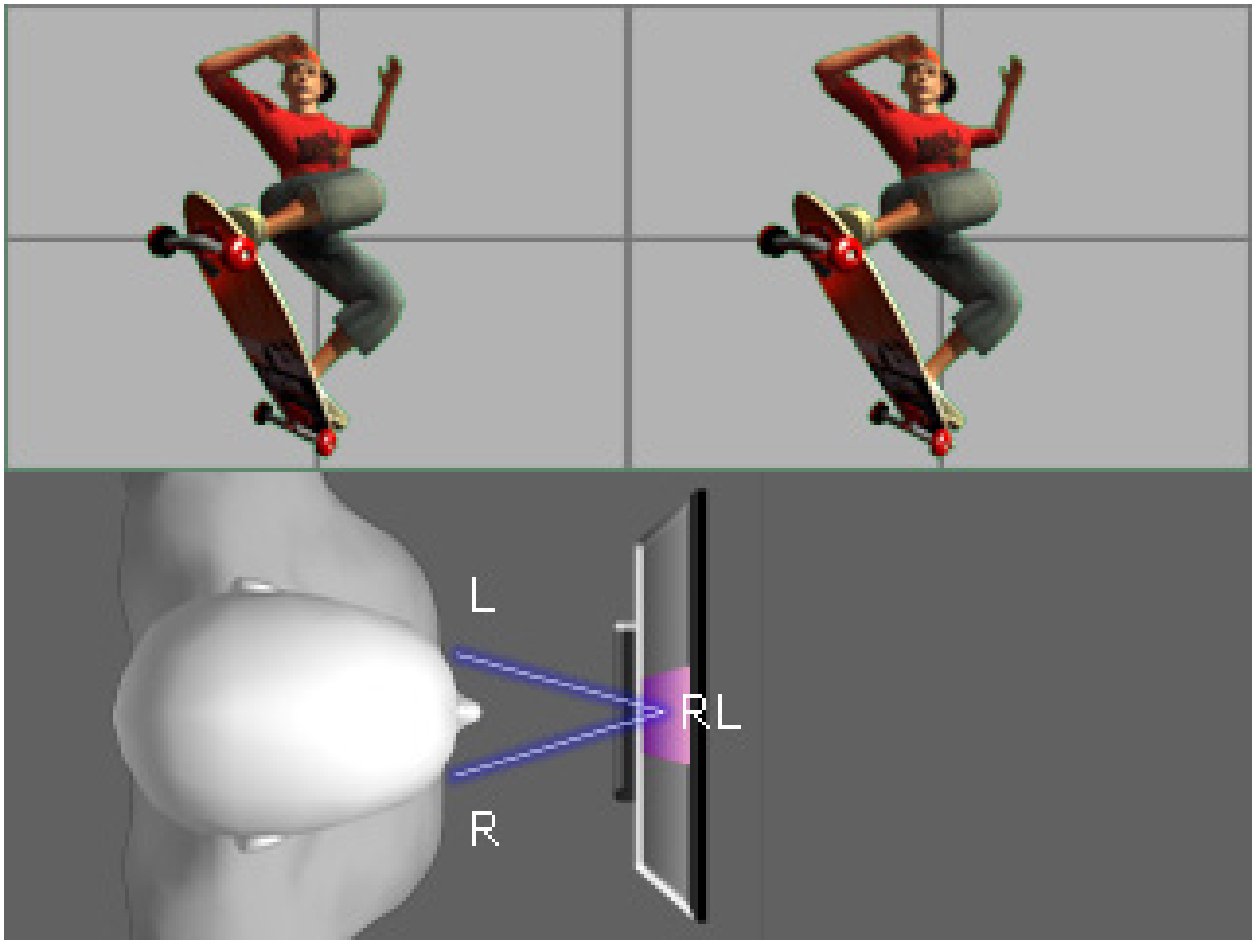
The L and R images lead your convergence point to fall in front of the display.

Zero parallax

- 3 types of parallax (3:3):
  - **<u>Zero parallax</u>** : If an object lies at the projection plane then its projection onto the focal plane is coincident for both the left and right eye, hence **zero parallax**.



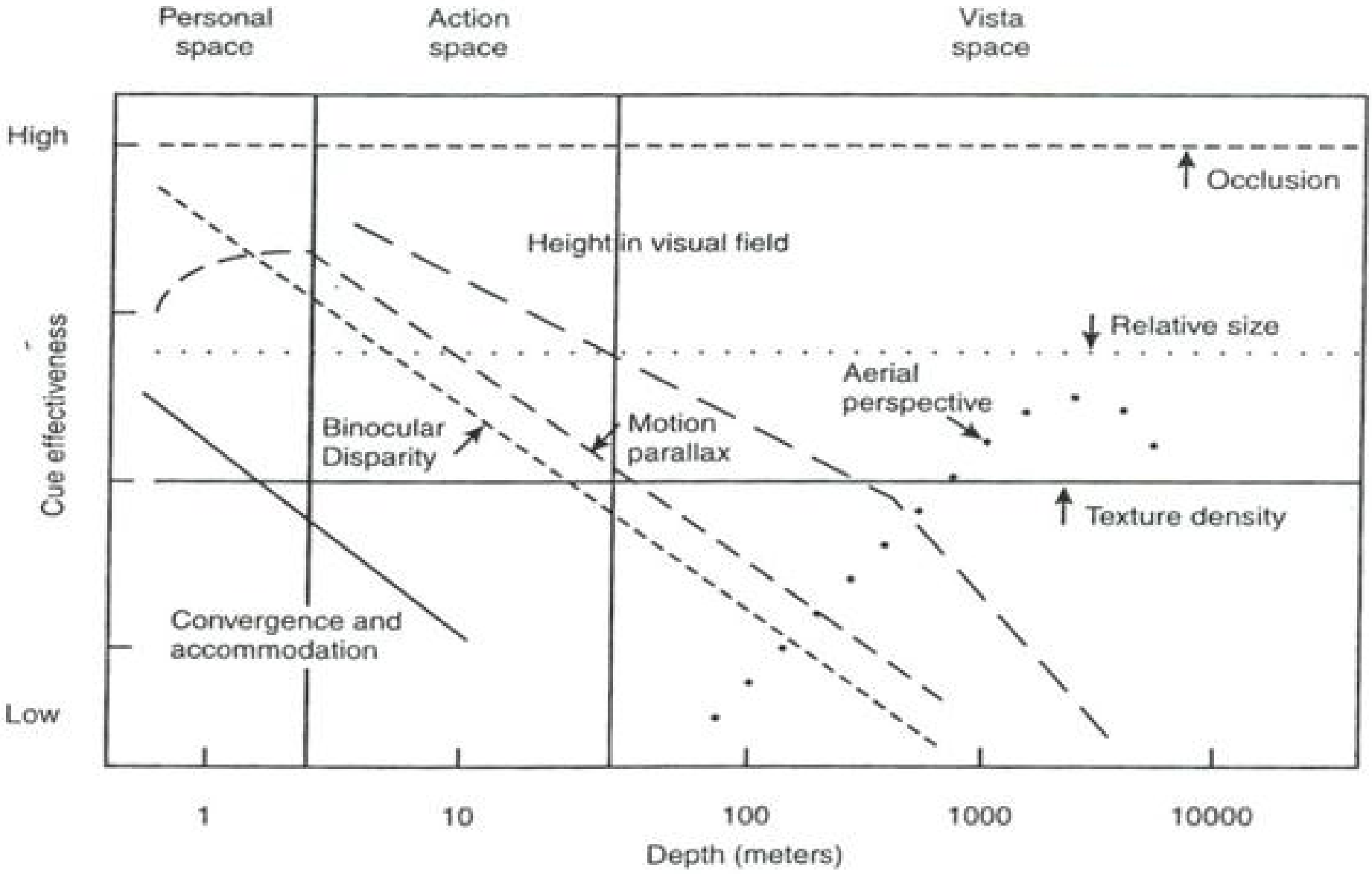
The L and R image lead your convergence point to fall on the display.



The L and R image lead your convergence point to fall on the display.

http://www.reallusion.com/iclone/Help/iClone5/Pro/09_3D_Vision/The_Concepts_of_Stereo_Vision.htm

Depth cues effectiveness : J. Cutting and P. Vishton

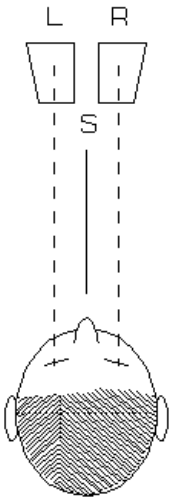


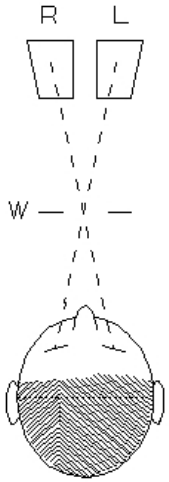
Stereoscopic delivery

- Perceive 3D image from 2 separated images
  - Perceptual effort
    - Wall-eyed or Cross-eyed
  - Individual optics
    - HMD
  - Filtering glasses
    - Anaglyph
    - Polarization
    - Shutter

Stereoscopic delivery: stereo pairs

- Wall-eyed or Cross-eyed



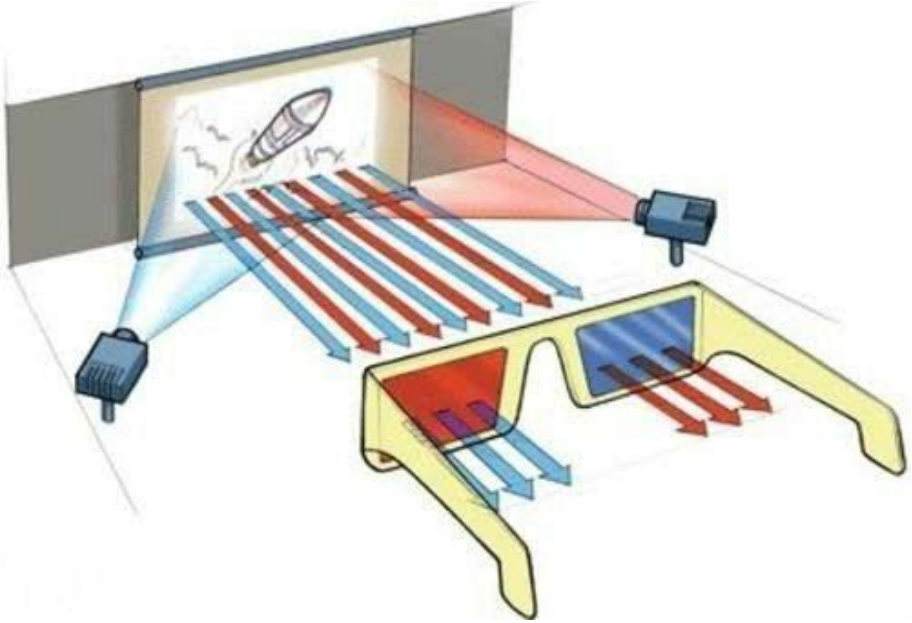


https://www.lhup.edu/~dsimanek/3d/view3d.htm

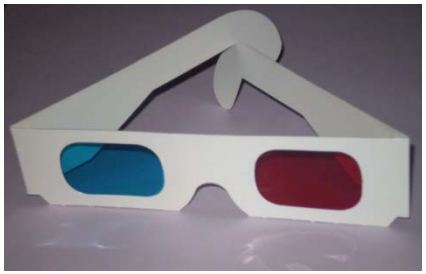
http://www.starosta.com/3dshowcase/ihelp.html

Stereoscopic delivery: anaglyph

- Anaglyph : Photography, cinema, TV, etc..

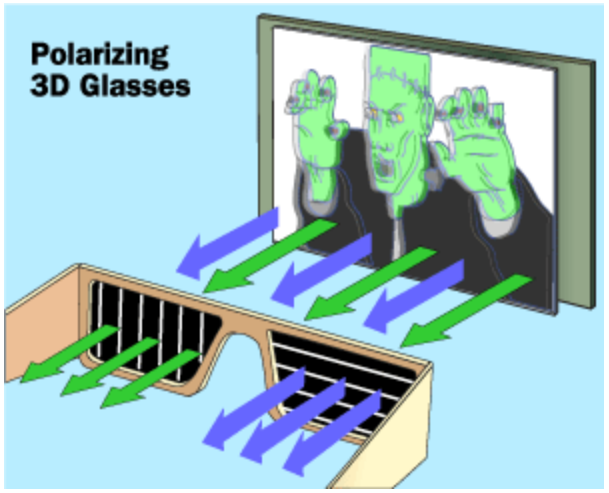


scheme	left eye	L	R	right eye	color rendering
red-green	pure red			pure green	monochrome
red-blue	pure red			pure blue	monochrome
red-cyan	pure red			pure cyan (green+blue)	color (poor reds, good greens)



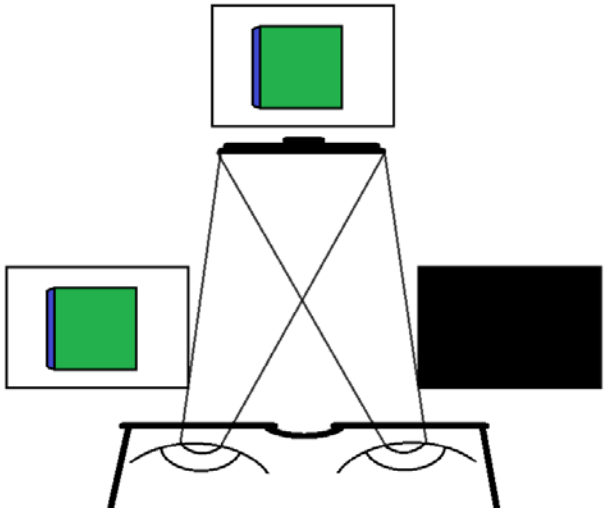
Stereoscopic delivery: polarized glasses

- Polarized glasses (passive) : two images are projected superimposed onto the same screen or displayed through different polarizing filters.



Stereoscopic delivery: shutter glasses

- Shutter glasses (active) :
  - presenting the image intended for the left eye while blocking the right eye's view
  - then presenting the right-eye image while blocking the left eye
  - repeating rapidly



Stereoscopic delivery (HMD)

- Most common 3D format
  - Side by side :

    - halving the horizontal resolution of videos to store left and right eye images in each frame

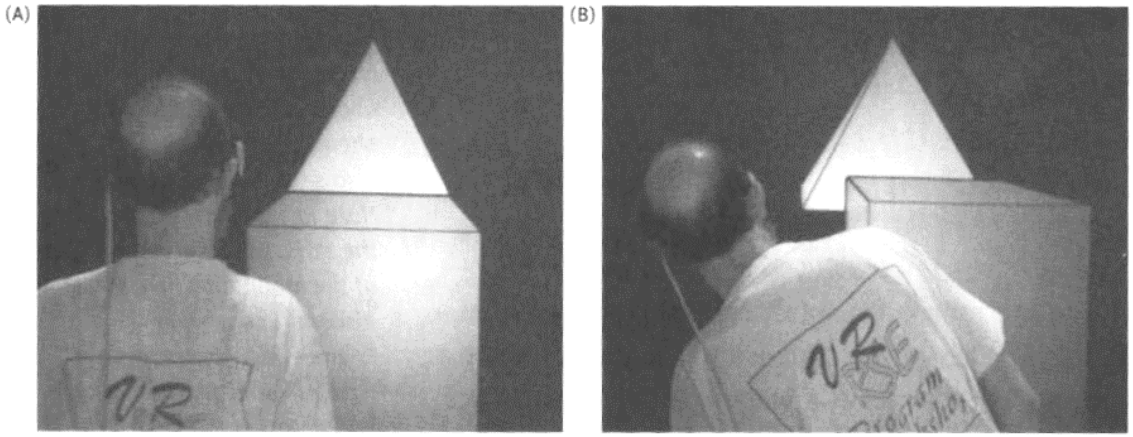
    - Provide full frame rate at the cost of image resolution

Side-by-Side

Conclusion

Stereopsis is only one means among many others to achieve depth perception. True stereopsis requests providing one image per eye (double computational cost compared to standard CG)

A powerful alternative at a cheaper cost is *motion parallax* as it requires a single image + viewpoint tracking.



[from R. Lindeman]

Depth is obtained through the viewpoint movement

Implementation details with OPEN GL are presented in the CAVE display course

Perceptual conflicts are developed in the Cybersickness course

Example of exploiting motion parallax :

Video from Henrique Galvan Debarba for the VR course (2016)

https://www.youtube.com/watch?v=6kZEjR6sLvU