Computational Photography

Prof. Feng Liu

Spring 2016

http://www.cs.pdx.edu/~fliu/courses/cs510/

05/24/2016

Last Time

- Video Stabilization

Today

- Stereoscopic 3D

Stereoscopic media

Digital Visual Effects

Yung-Yu Chuang

3D is hot today

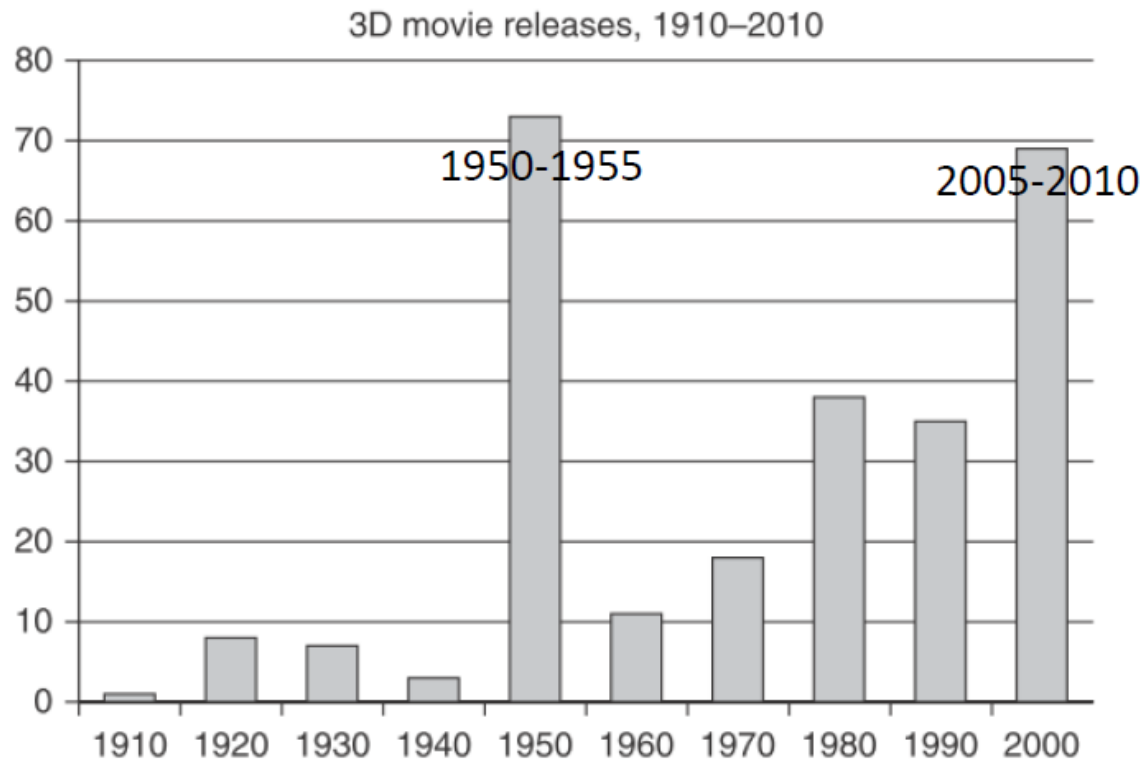
3D has a long history

- 1830s, stereoscope
- 1920s, first 3D film, *The Power of Love*
  projected dual-strip in the red/green anaglyph format
- 1920s, teleview system

Teleview was the earliest alternate-frame sequencing form of film projection. Through the use of two interlocked projectors, alternating left/right frames were projected one after another in rapid succession. Synchronized viewers attached to the arm-rests of the seats in the theater open and closed at the same time, and took advantage of the viewer's persistence of vision, thereby creating a true stereoscopic image.

3D has a long history

- 1950s, the "golden era" of 3-D
- The attempts failed because immature technology results in viewer discomfort.
- 1980s, rebirth of 3D, IMAX



Why could 3D be successful today?

- It finally takes off after digital processing makes 3D films both easier to shoot and watch.
- New technology for more comfortable viewing experiences
  - Accurately-adjustable 3D camera rigs
  - Digital processing and post-shooting rectification
  - Digital projectors for accurate positioning
  - Polarized screen to reduce cross-talk

3D TVs

Computers

Notebooks

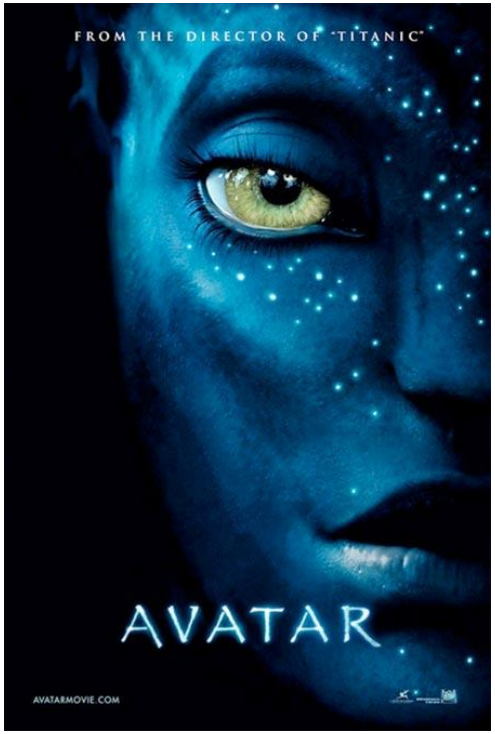
Game consoles

HTC EVO 3D

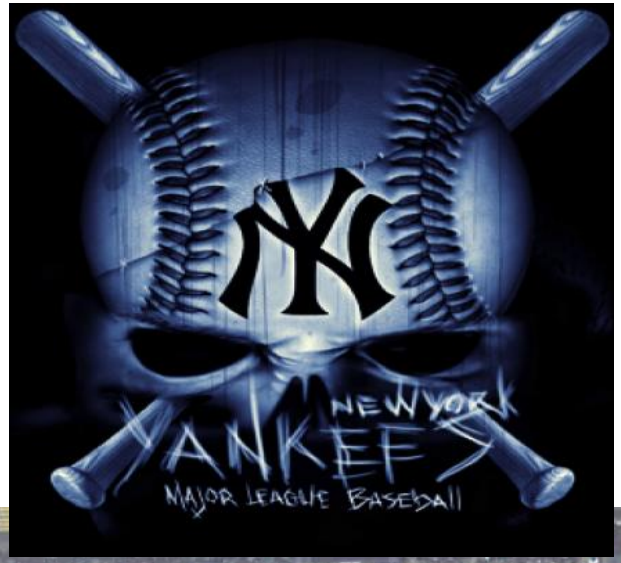

htc
10:08 AM
10
08
AM
Seattle
Mostly Sunny
Tue, Mar 22
50°
Tips
Messages
Mail
Phone
htc
3D
dcfever.com

3D contents (games)

3D contents (films)



3D contents (broadcasting)



3D cameras


75mm
BASE LINE LENGTH
TWIN CCD
3D HD
3D
FUJIFILM
MENU /OK
3D
2D↔3D

Sony HDR-TD10E

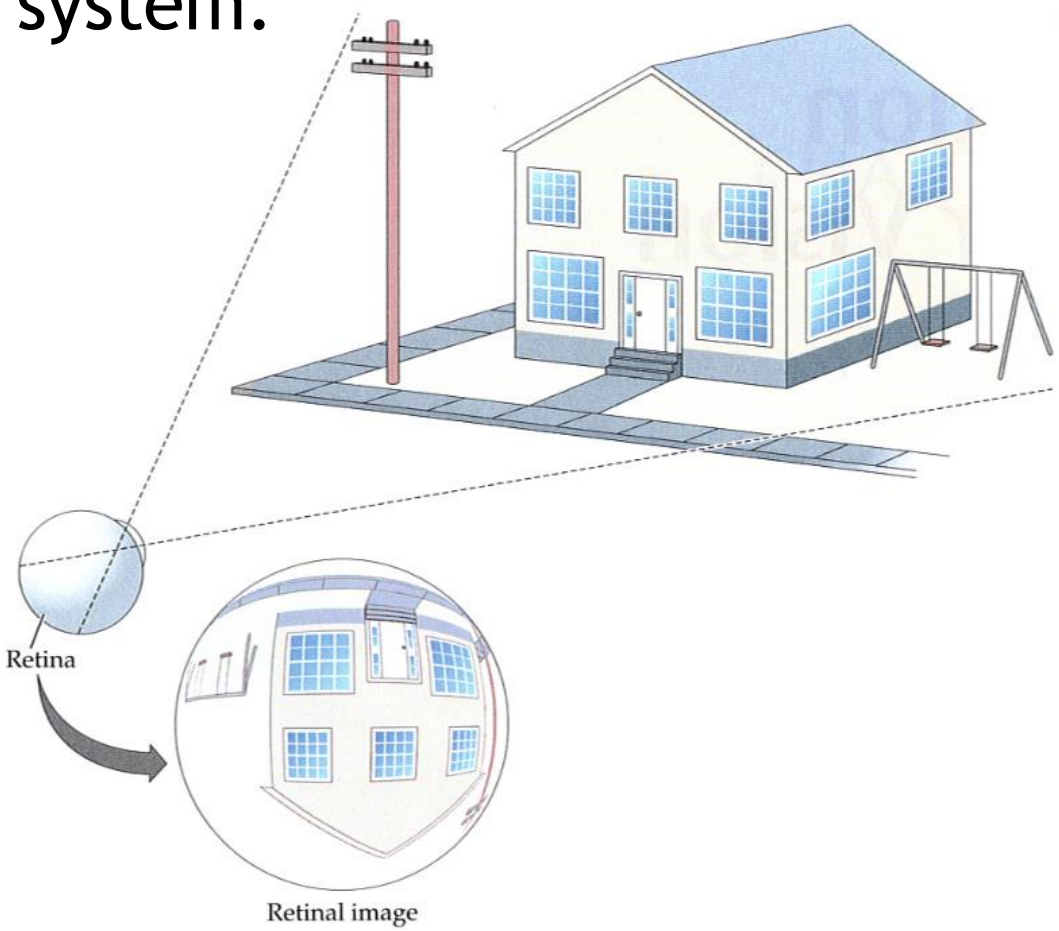
Outline

- Human depth perception
- 3D displays
- 3D cinematography
- Stereoscopic media post-processing

Human depth perception

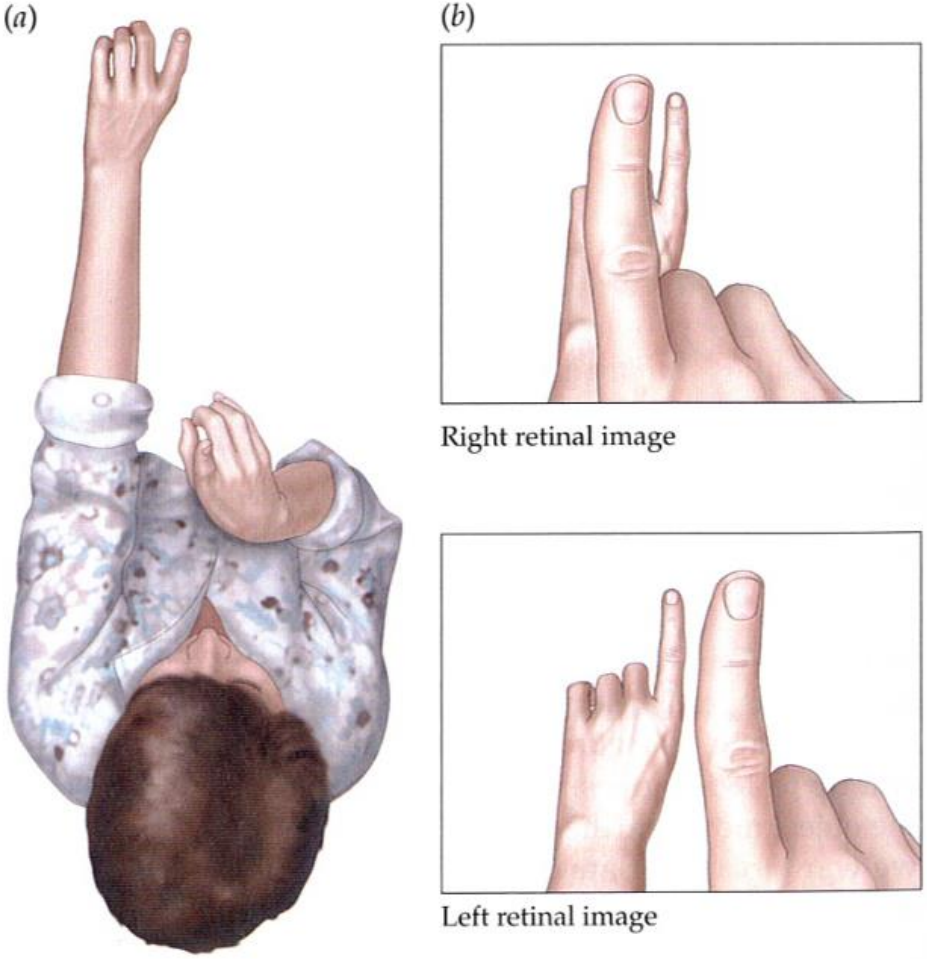
Space perception

- The ability to perceive and interact with the structure of space is one of the fundamental goals of the visual system.



Binocular vision

- Two retinal images are different because the retinas are in slightly different places.
- The combination of signals from each eye makes performance on many tasks better with both eyes than with either eye alone.

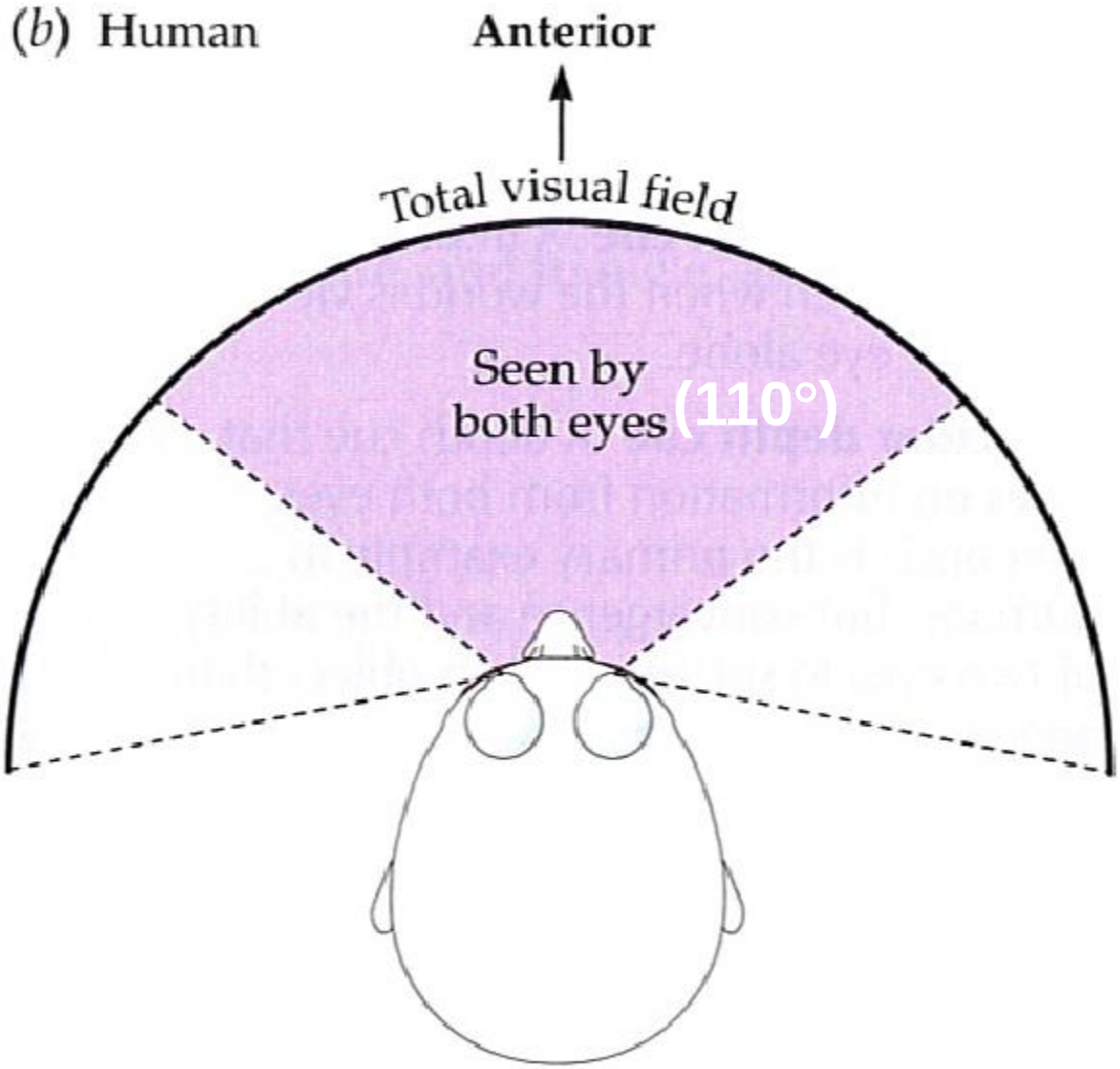


Binocular disparity

- **Binocular disparity**: the differences between the two retinal images of the same scene.
- **Monocular**: with one eye
- **Stereopsis**: the ability to use binocular disparity as a cue to depth.

- Note that, although stereopsis adds richness to depth perception, it is not a necessary condition for depth perception.
  - Example: rabbits and 2D films.

Binocular vision



Animal Stereo Vision

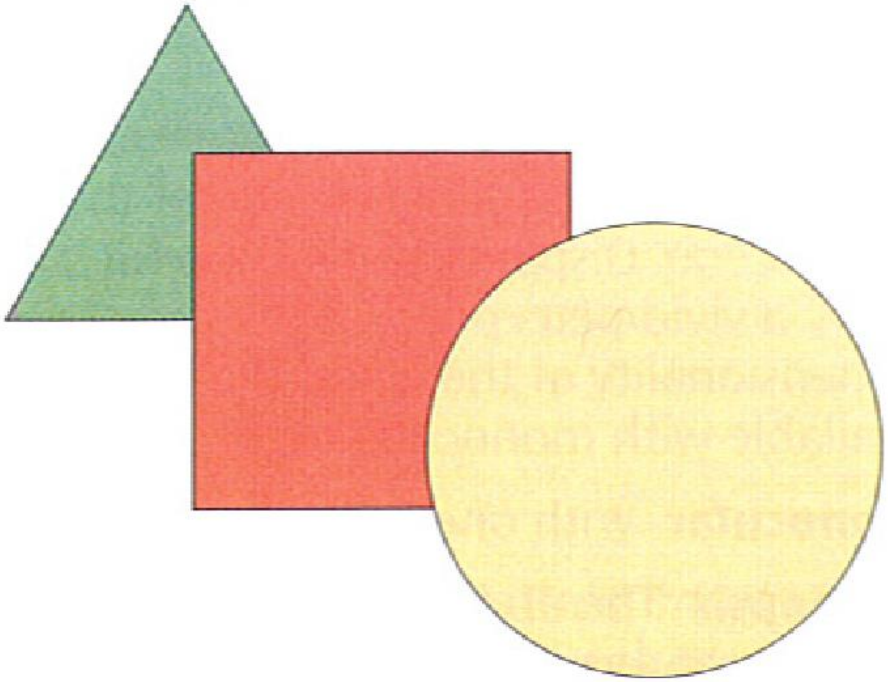



Monocular cues to 3D space

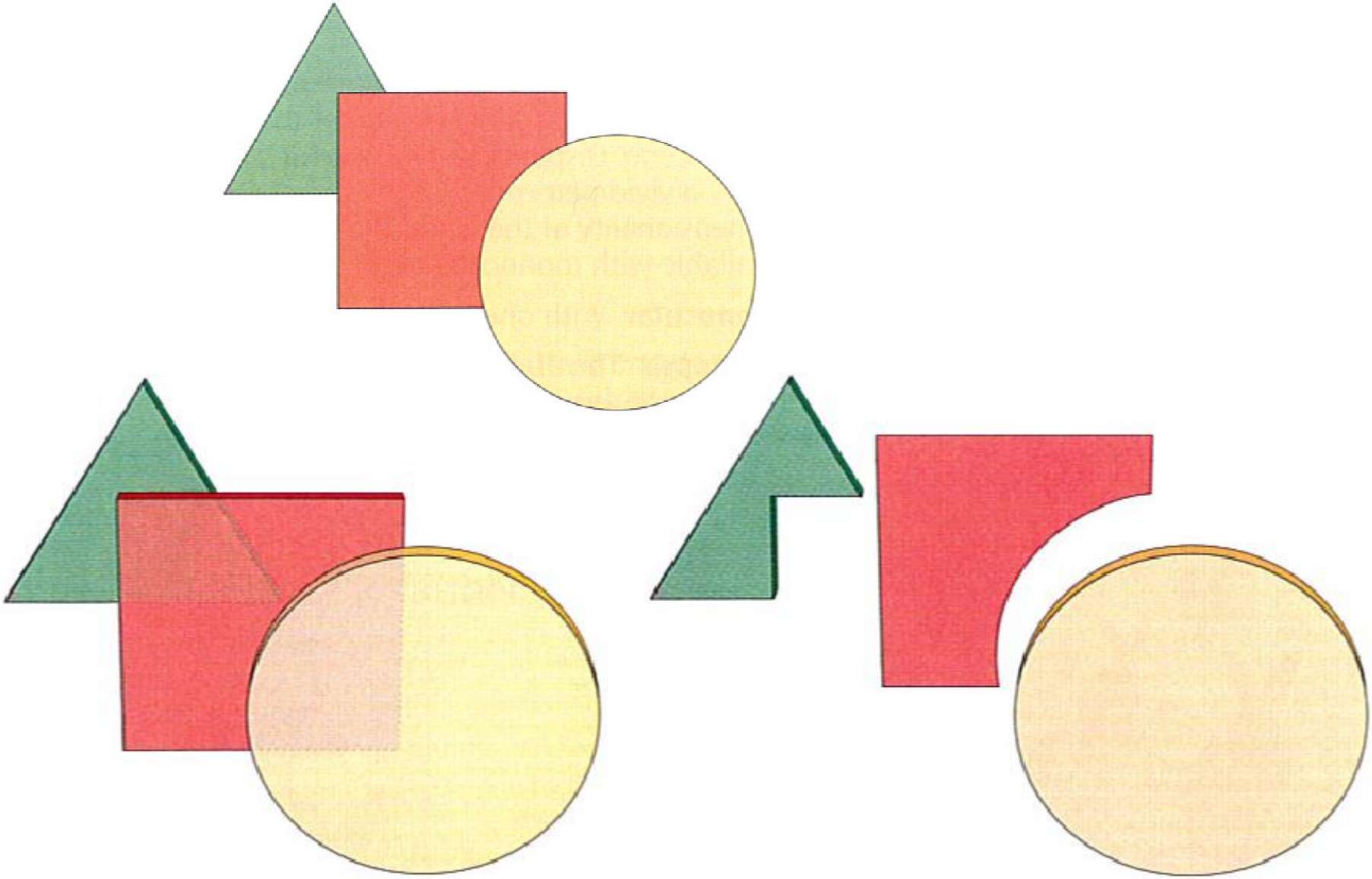
- Every view of the world provides multiple depth cues.
- Usually, the cues reinforce each other, combining to produce a convincing and reliable representation of 3D world.
- Occasionally, however, the cues are contradictory.

Occlusion

- Occlusion gives relative position of objects as a depth cue.
- It occurs in almost every scene and some argues that it is the most reliable depth cue.

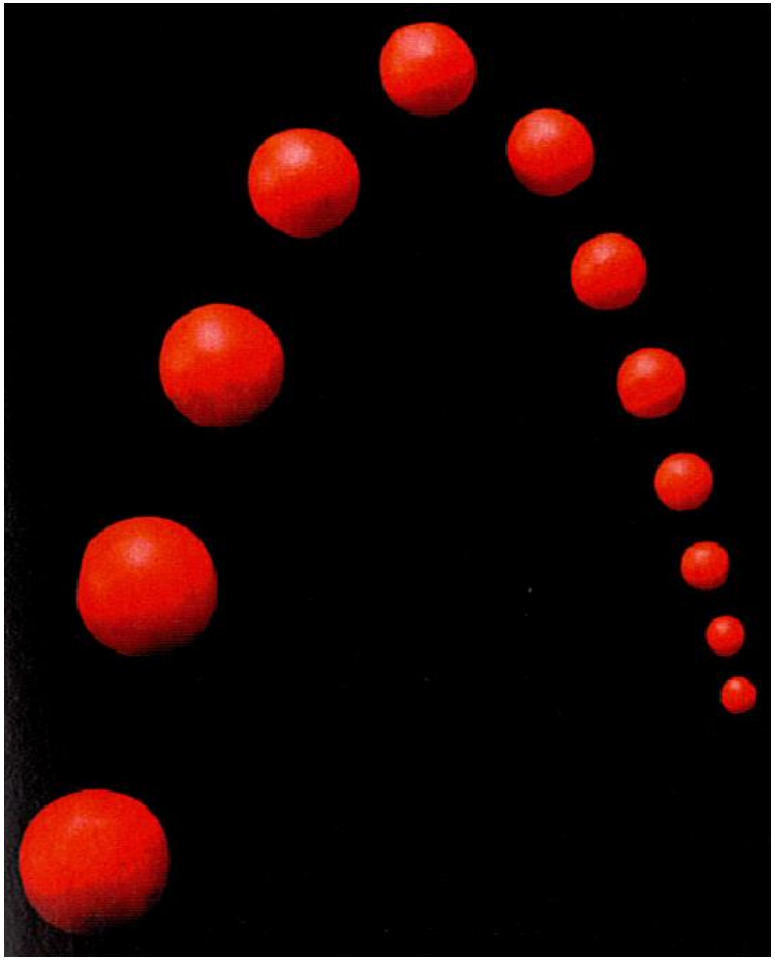


Occlusion

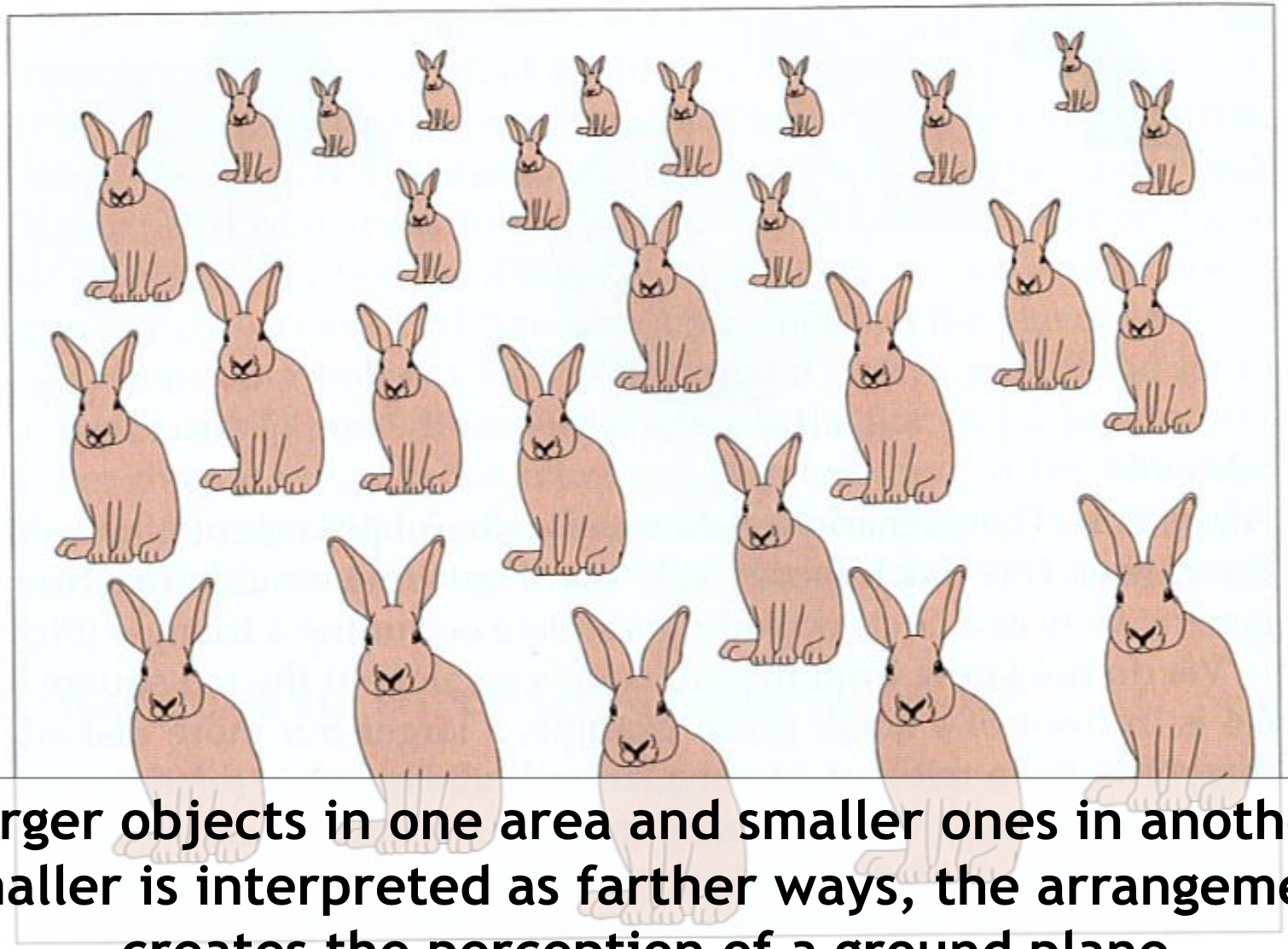


Size and position cues

- We have projective geometry embedded. We know that, all else being equal, smaller things are farther away.

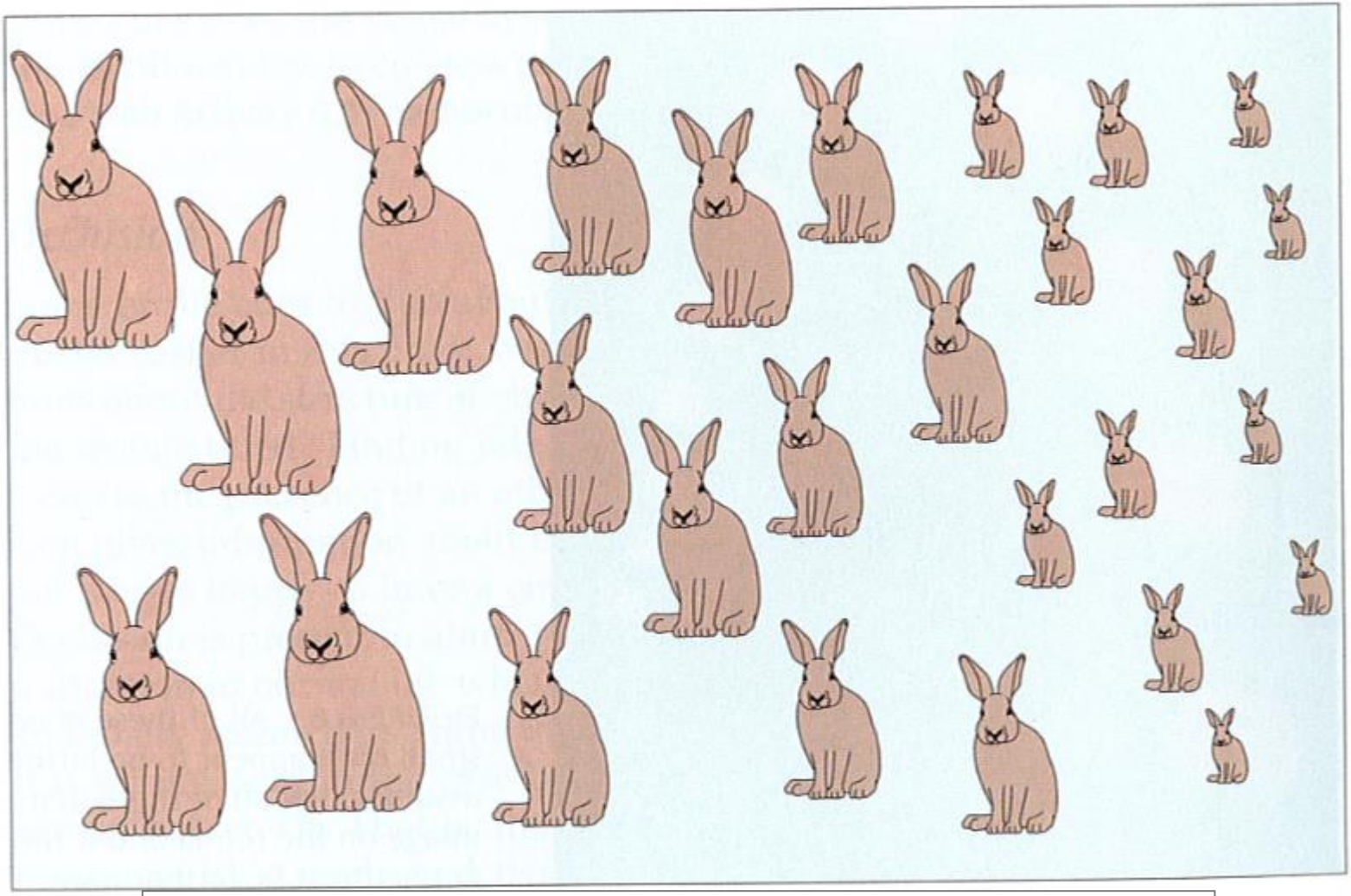


Texture gradient



Larger objects in one area and smaller ones in another. Smaller is interpreted as farther ways, the arrangement creates the perception of a ground plane.

Texture gradient

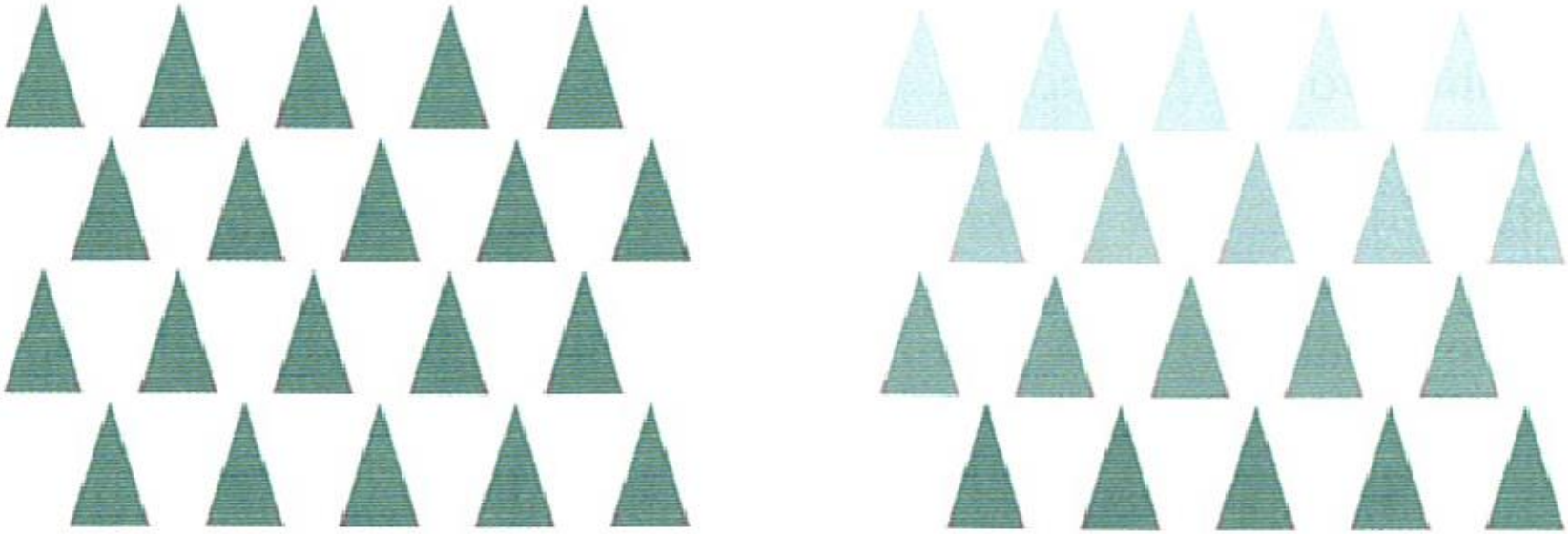


Why do we get less of a sense of depth?

Familiar size

Familiar size: a depth cue based on knowledge of the typical size of objects.

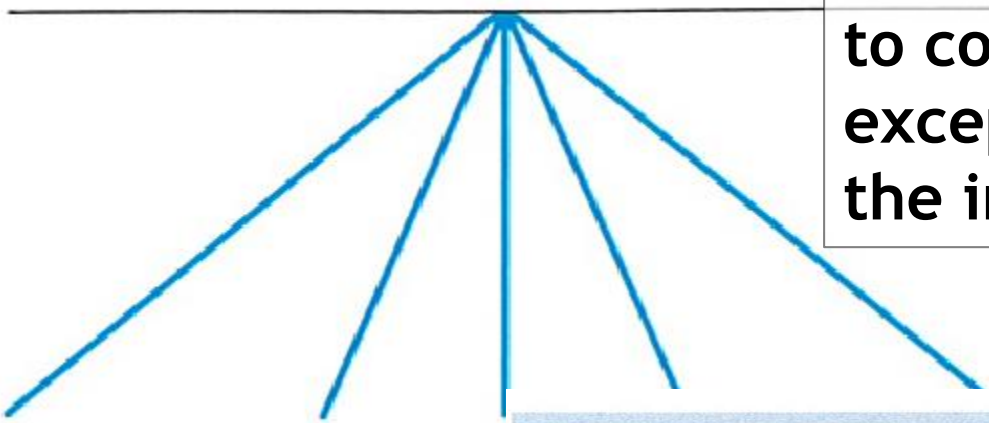
Aerial perspective



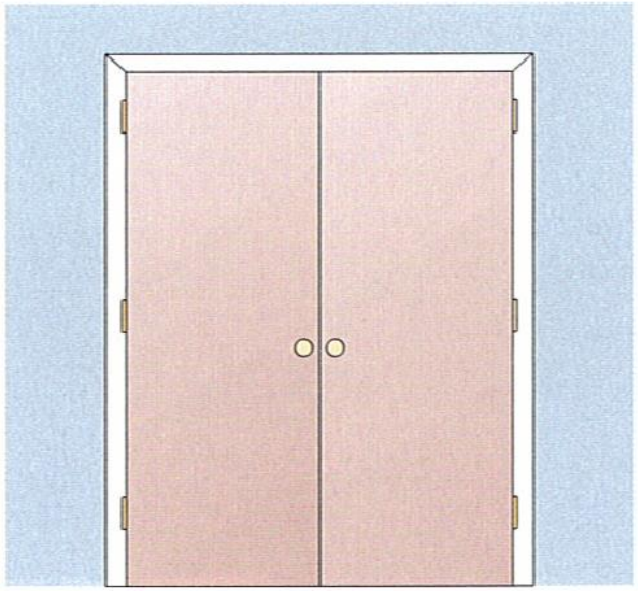
Aerial (haze) perspective: light is scattered by the Atmosphere, and more light is scattered when we Look through more atmosphere.

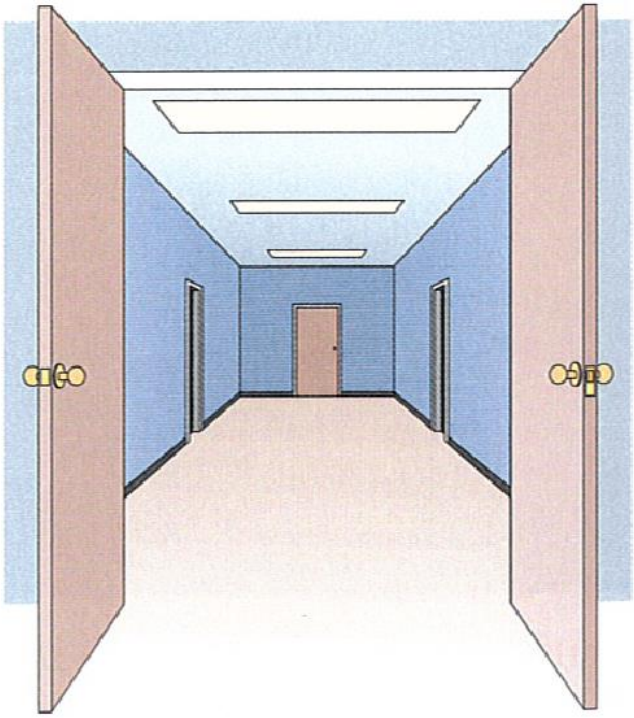
Aerial perspective

Linear perspective

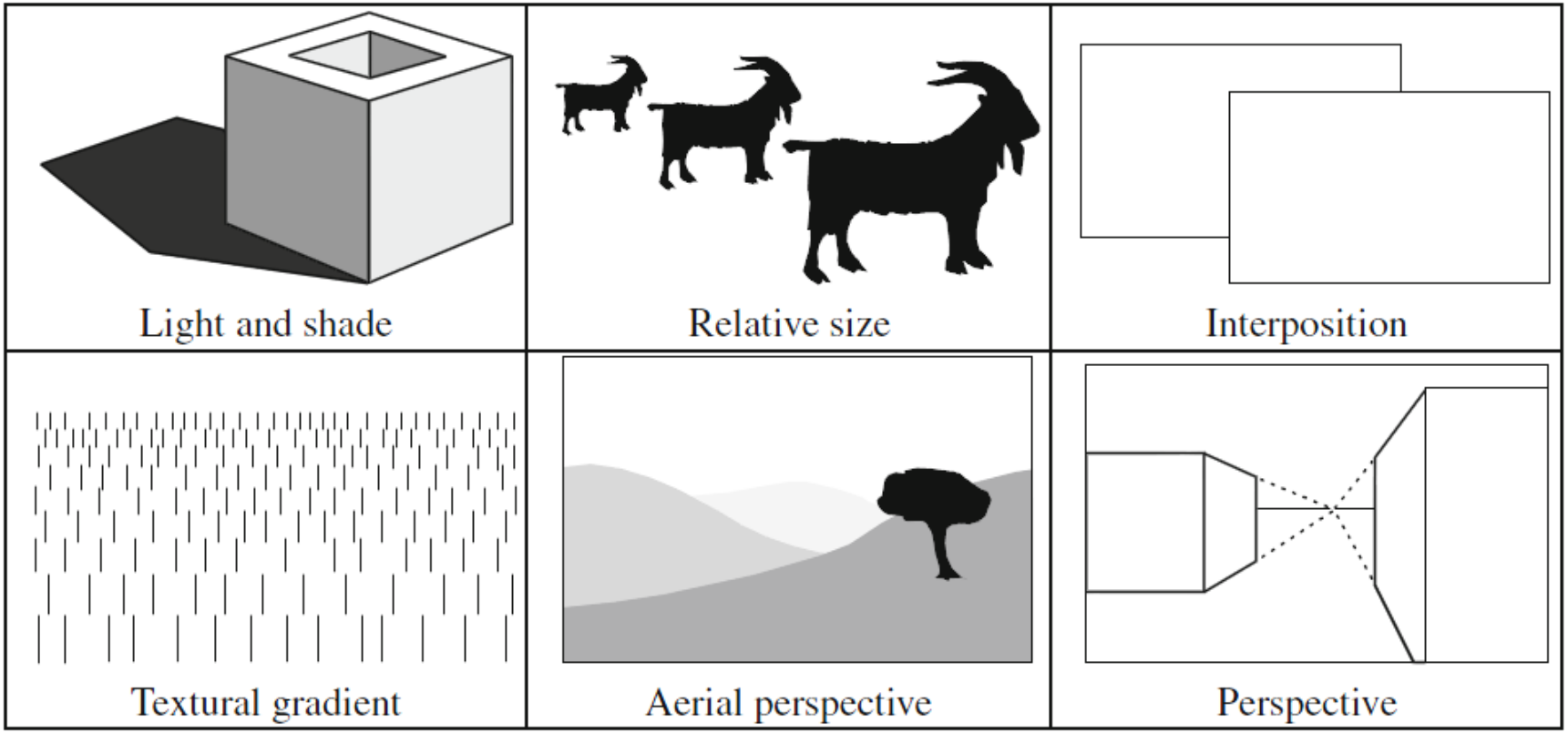


Parallel lines in 3D world appear to converge in the 2D image, except for the ones parallel to the image plane.





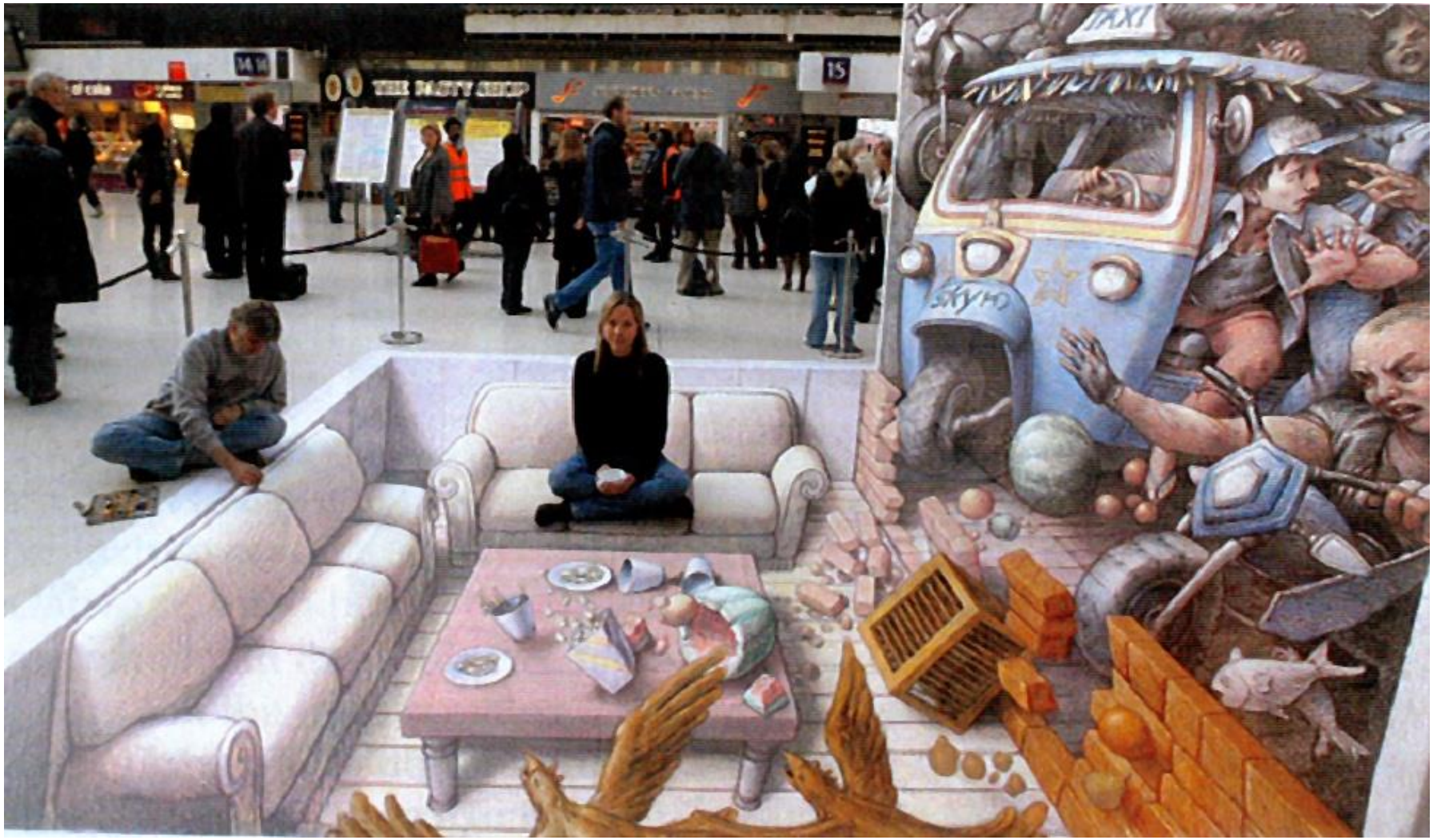
Monocular cues



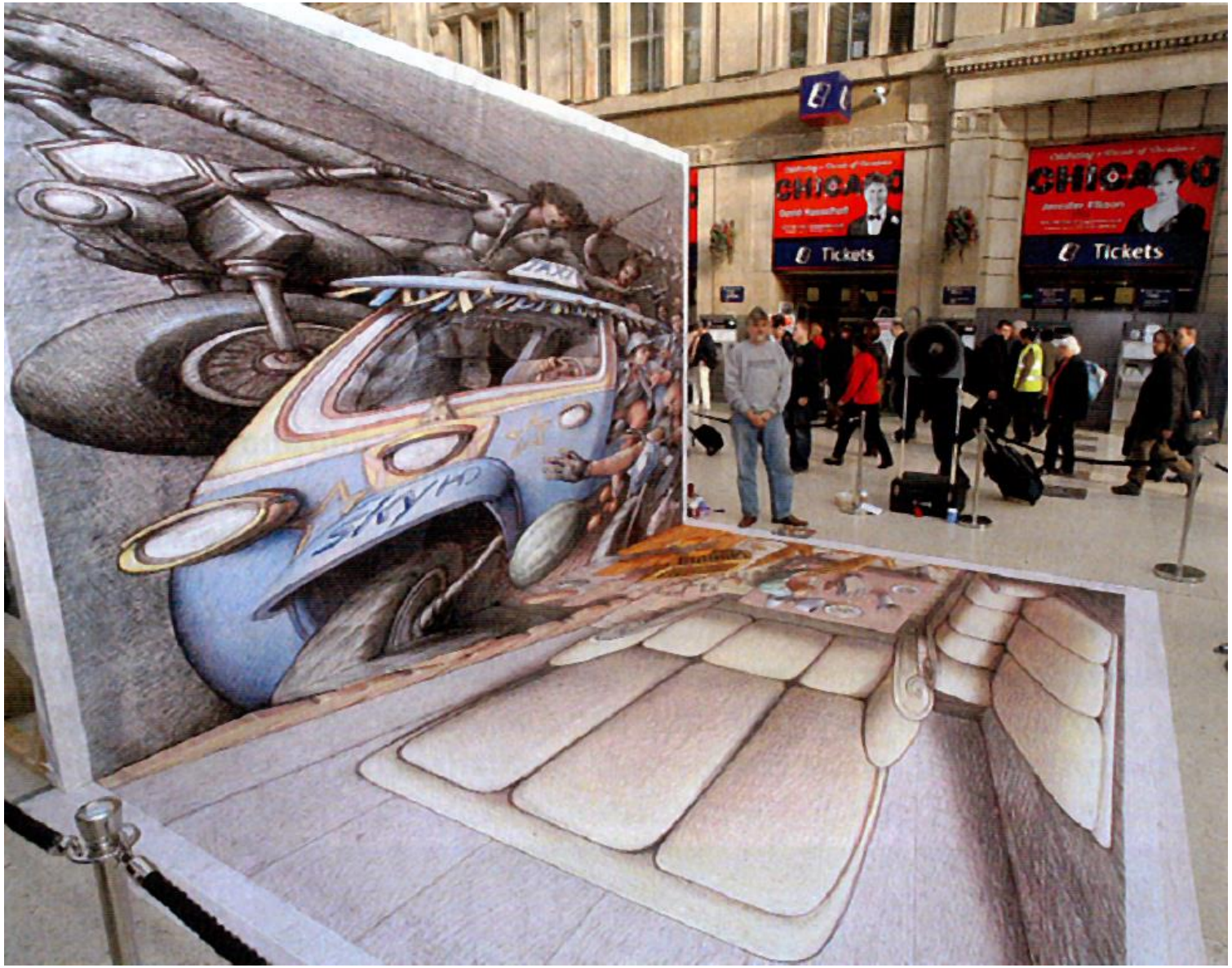
Pictorial depth cues

- All these monocular cues are pictorial depth cues produced by the projection of the 3D world onto the 2D surface of the retina.
- Combined with proper shading, these cues could be effective in illustrating 3D.

Pictorial depth cues



Pictorial depth cues



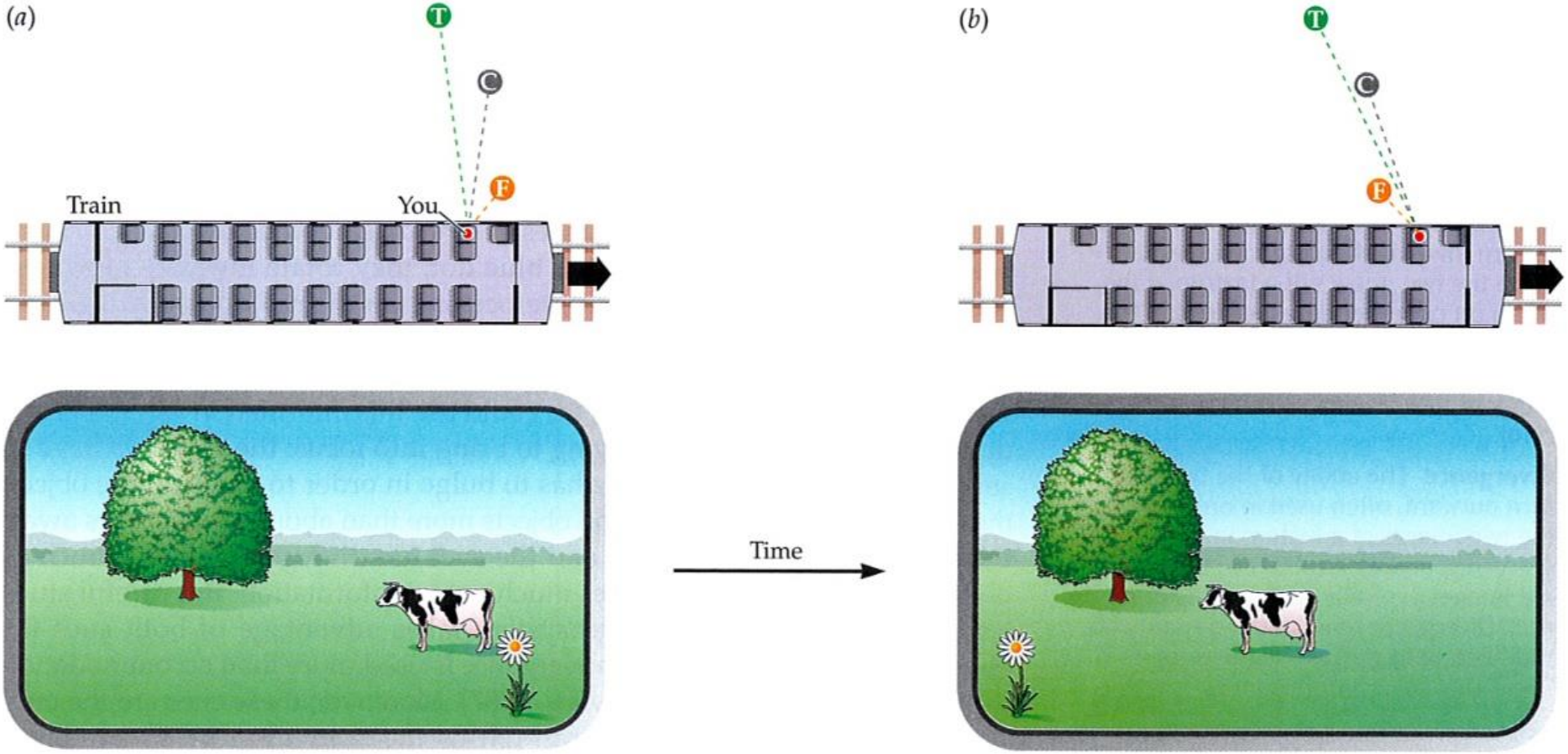
Pictorial depth cues

Monocular cues

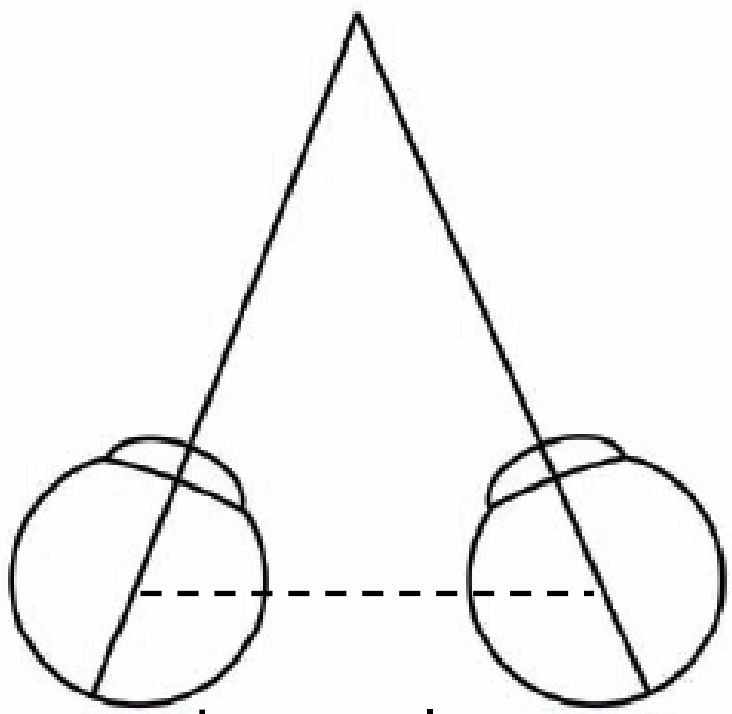
- Because there are lots of monocular cues and they are not less important than binocular ones, some images could look more stereoscopic than others. Example, 2D-to-3D conversion is easier for some images but more difficult for others.

Motion cues

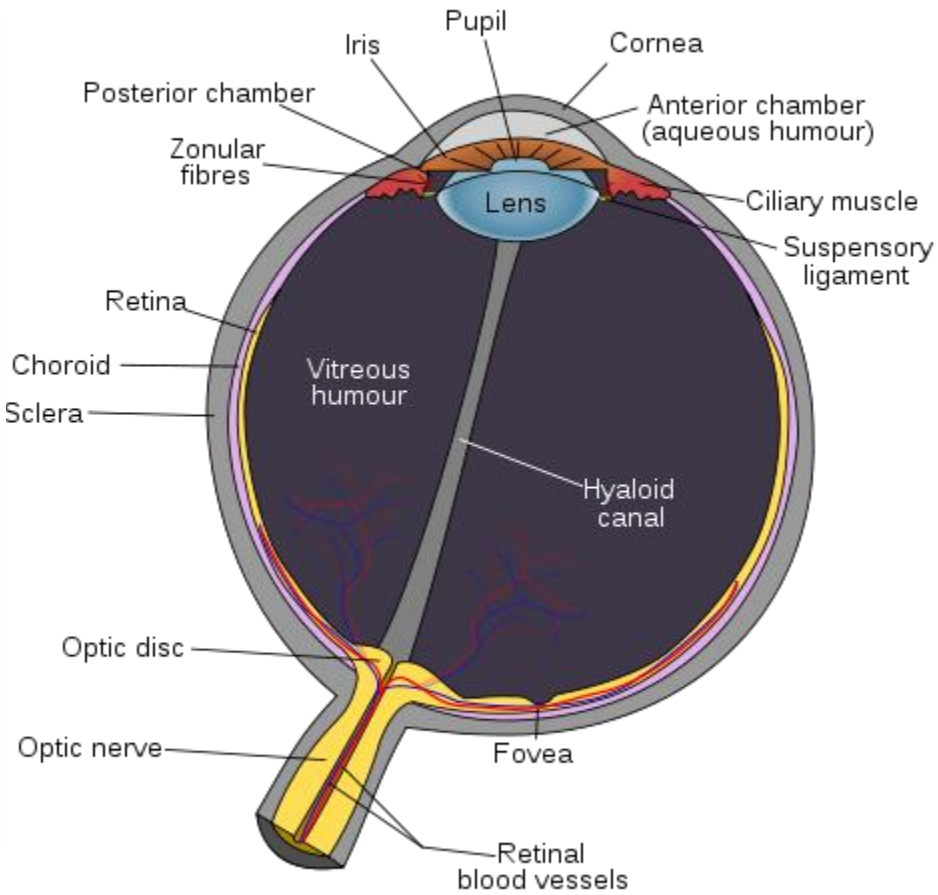
- **Motion parallax** is a non-pictorial depth cue. When your head moves, closer objects move faster than more distant ones.



Binocular vision

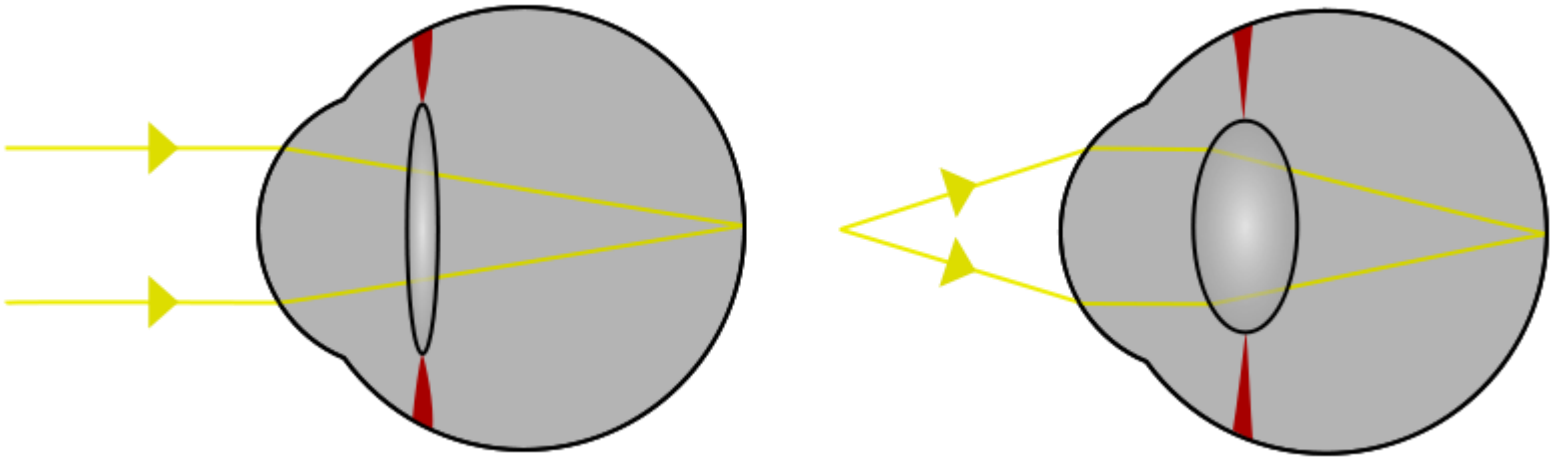


interocular distance ~6.5cm

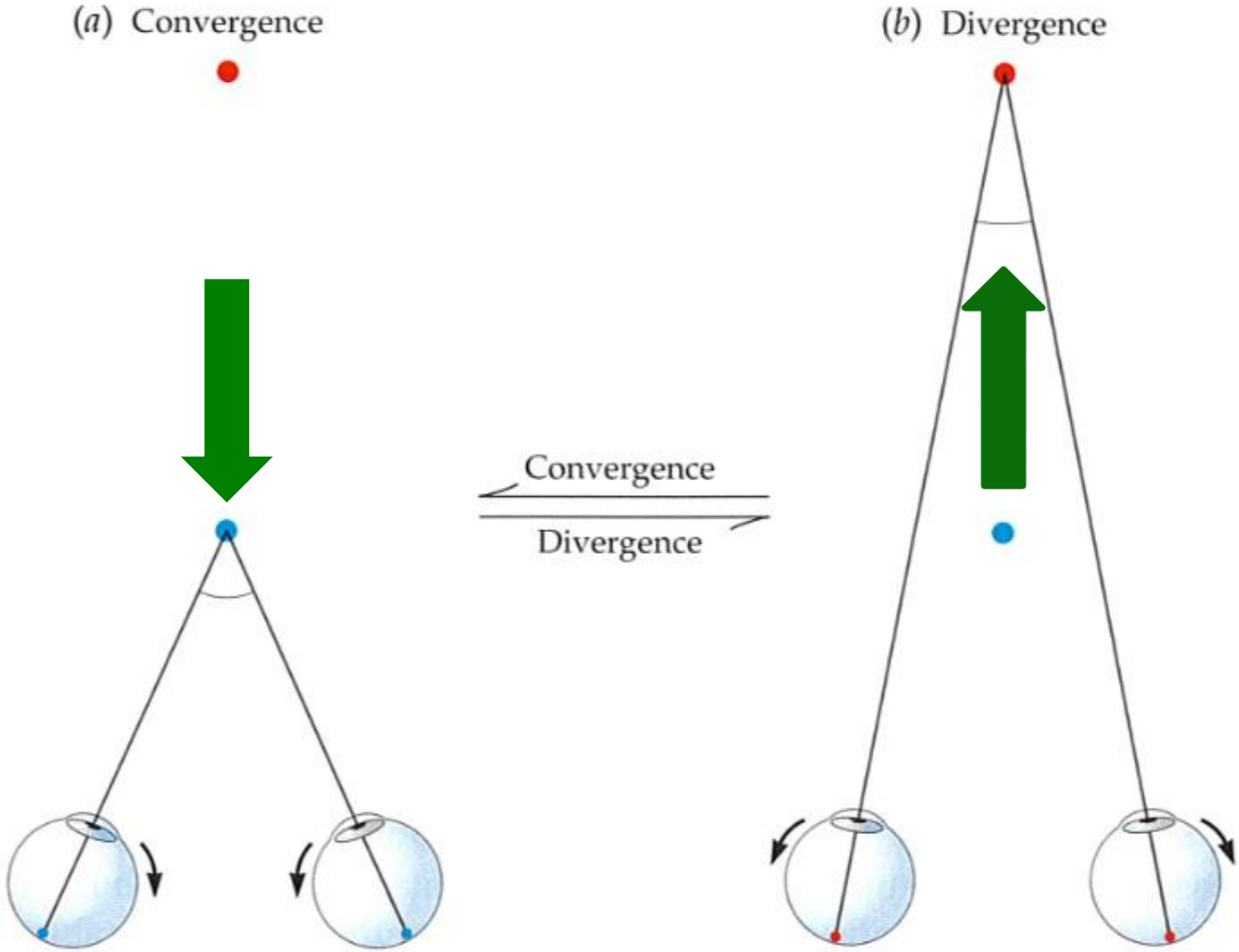


Accommodation and convergence

- Eyes need to be focused to see objects at different distances clearly.
- Human eye focuses via a process called accommodation, in which lens gets fatter as we direct our gaze toward nearer objects.



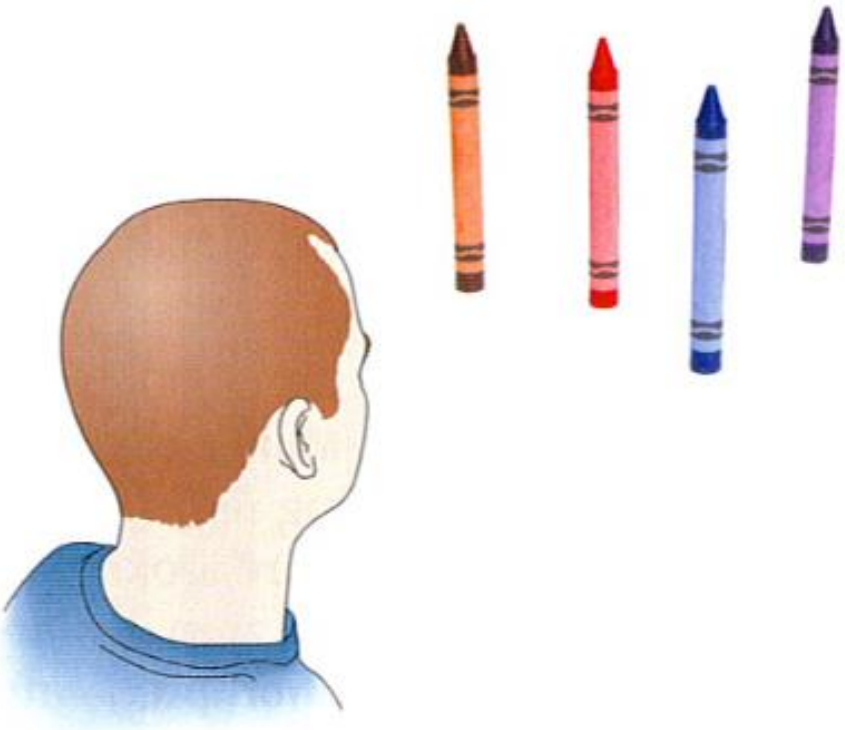
Accommodation and convergence

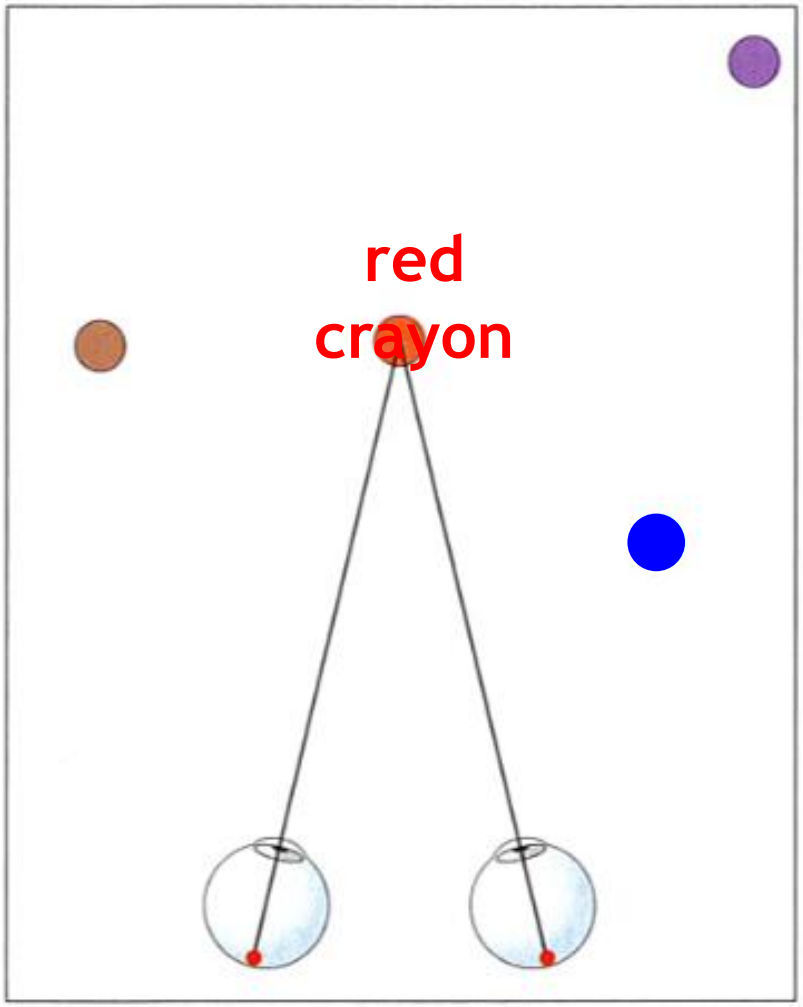


Accommodation and convergence

- Human can perceive depth by accommodation and convergence.

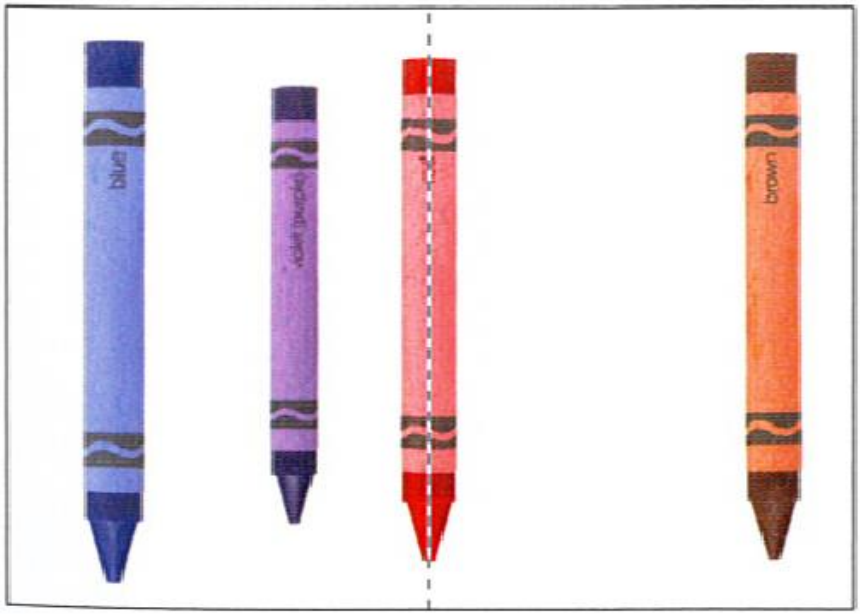
Binocular vision



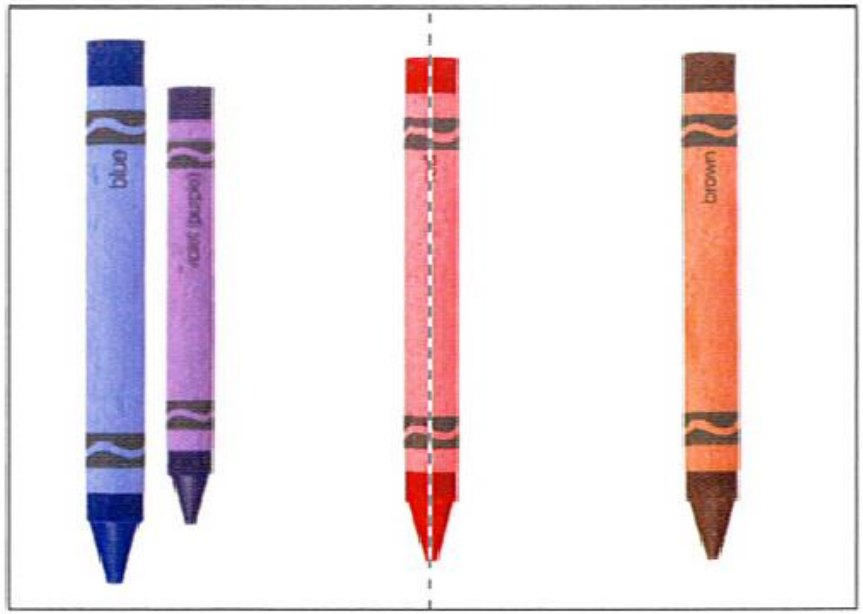


Binocular vision

- Note that the retinal images are inverted. The object of our gaze falls on the fovea, center of the retina.
- The blue one happens to fall on **corresponding retinal points**.

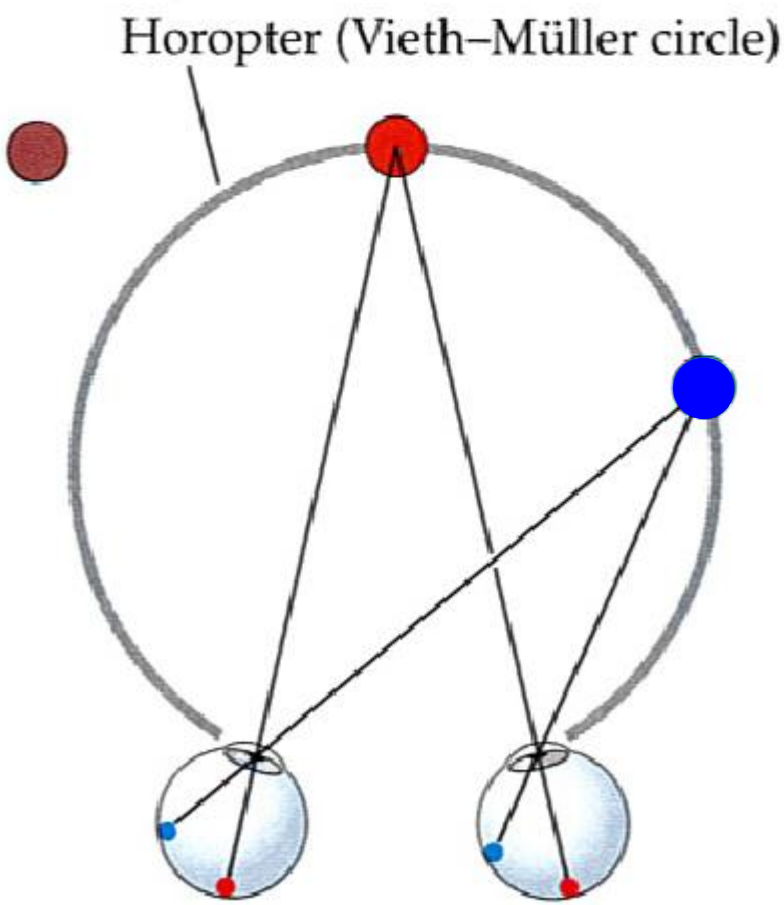


Left retinal image



Right retinal image

Binocular vision

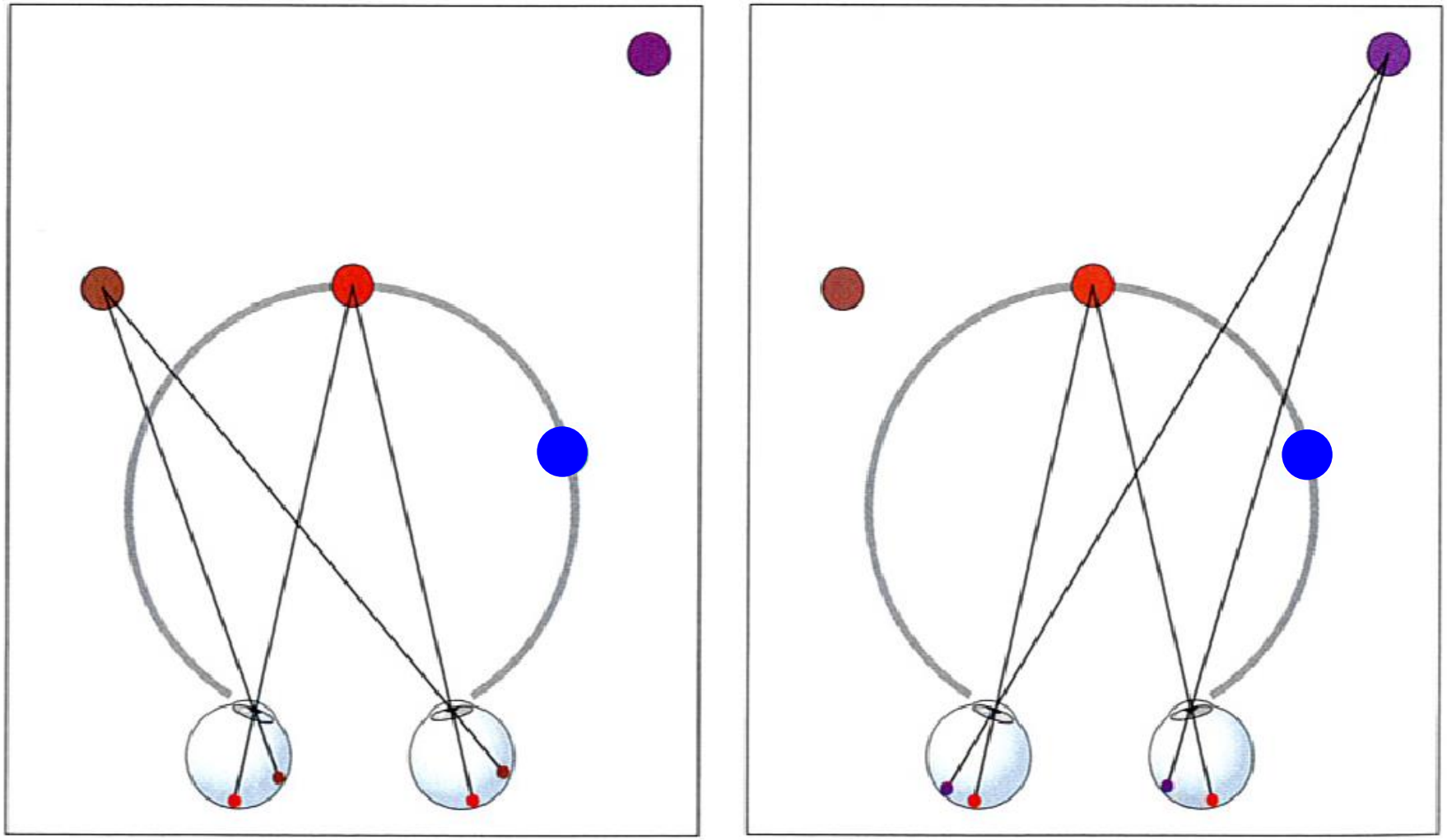


Horopter: the surface with zero disparity.

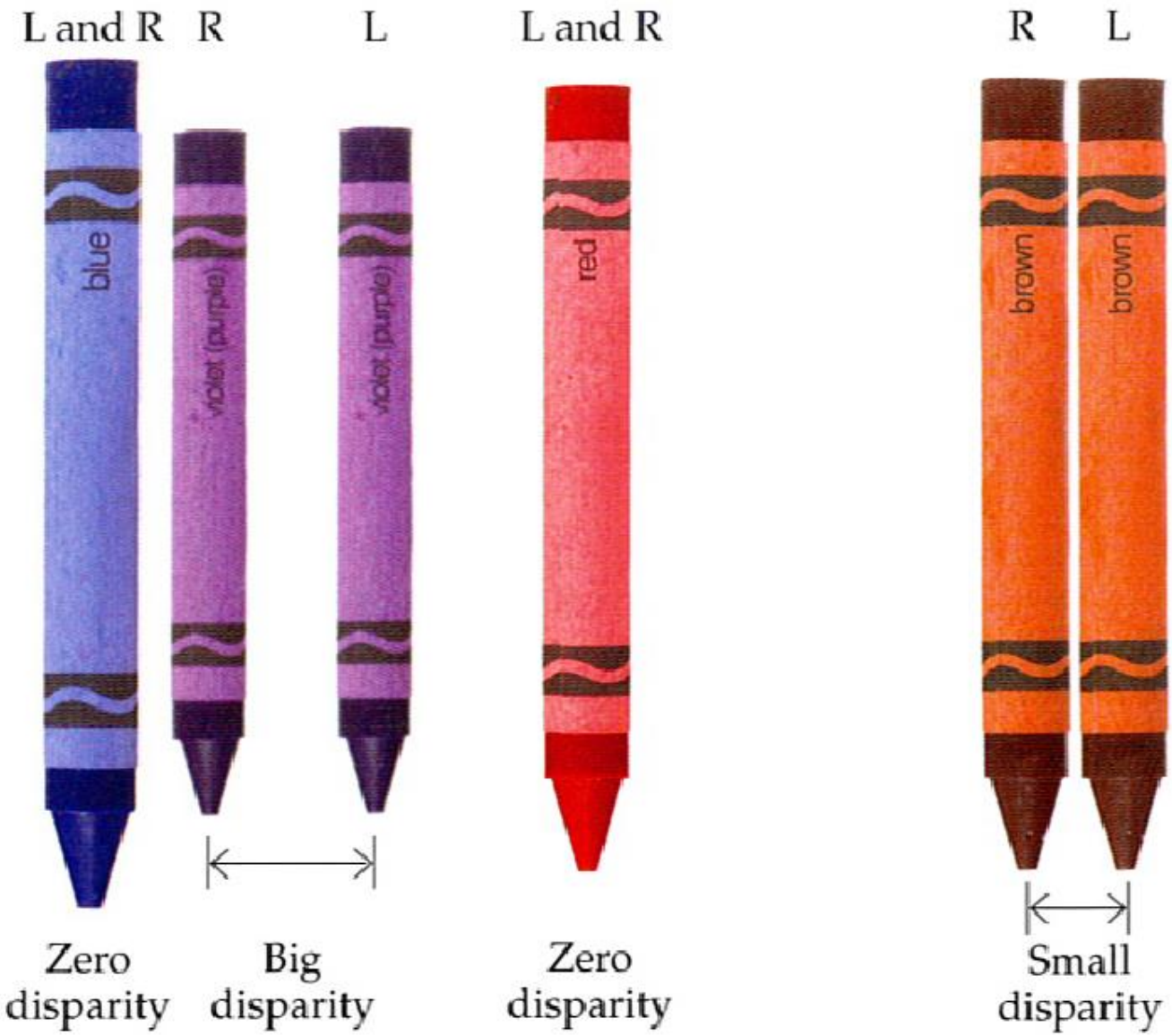
Panum's fusional area: the region of space, in front of and behind the horopter, within which binocular vision is possible.

Diplopia: double vision

Binocular vision



Binocular vision



Stereo image

Left

Right

Stereo image

Binocular vision

- Our nervous system cannot measure the angle very accurately. Thus, we can only perceive relative depth.
- The role of eye movement is to bring the images within Panum's fusional area.

Stereoblindness

- An inability to make use of binocular disparity as a depth cue.
- Approximately 3% to 5% of the population lacks stereoscopic depth perception.

Summary

- Monocular cues: occlusion, size and position cues, aerial perspective, linear perspective.
- Motion cues
- Accommodation and convergence cues
- Binocular cues

3D displays

3D displays

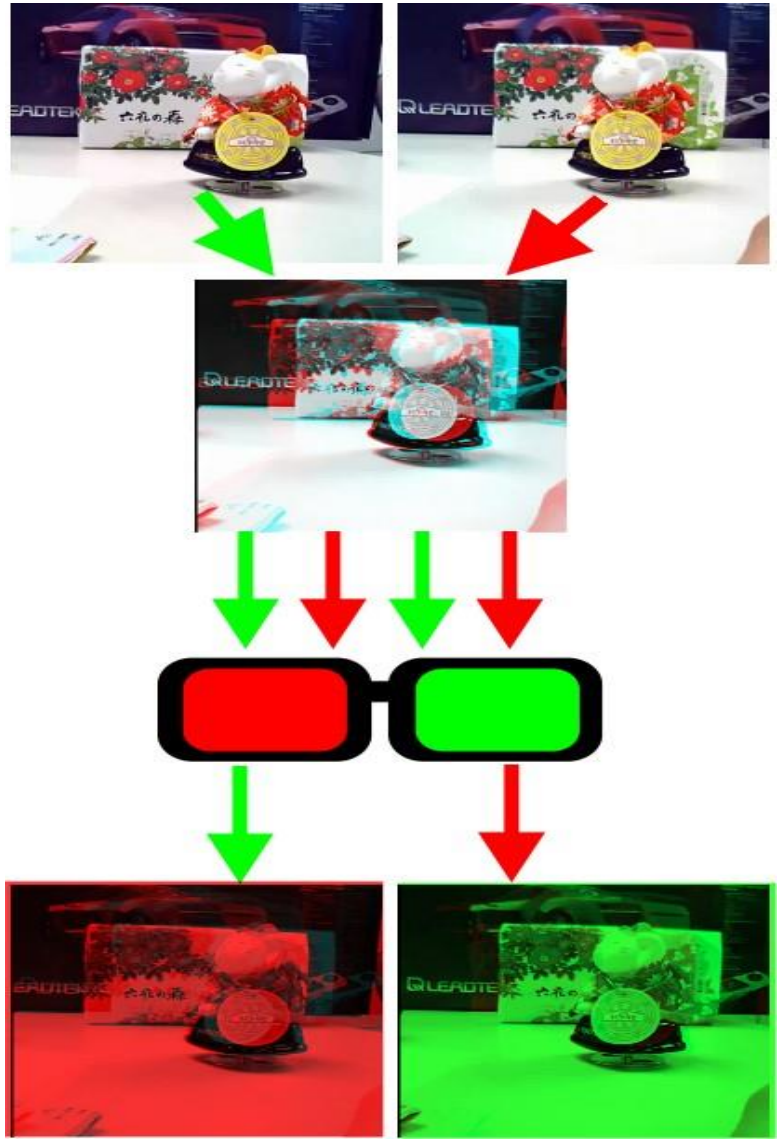
- Glasses
  - Anaglyph glasses
  - Polarized glasses
  - Shutter glasses
  - Head-mounted
- Glasses-free
  - Holography
  - Volumetric displays
  - Integral imaging
  - Auto-stereoscopic

3D displays

- Note that monocular cues can be produced by rendering/capturing the contents correctly.
- Most 3D displays enrich space perception by exploiting binocular vision. Thus, they have to present different contents to each of both eyes.

With glasses

Anaglyph glasses

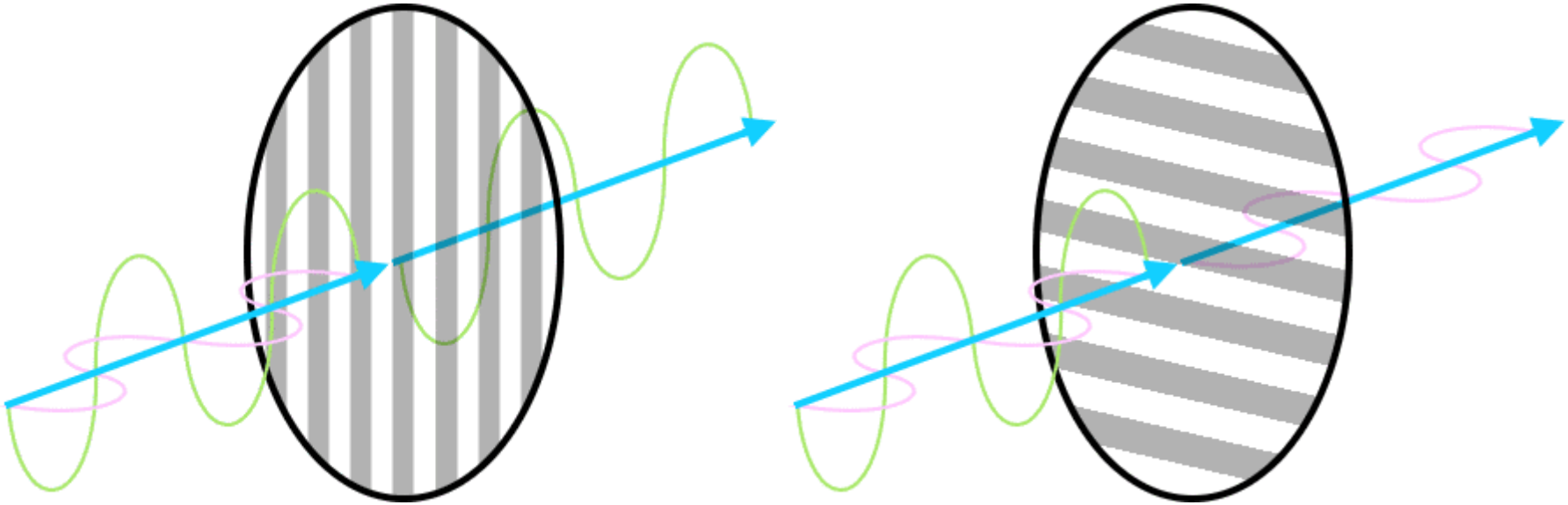


Many color formats
Supported by YouTube and
Google StreetView

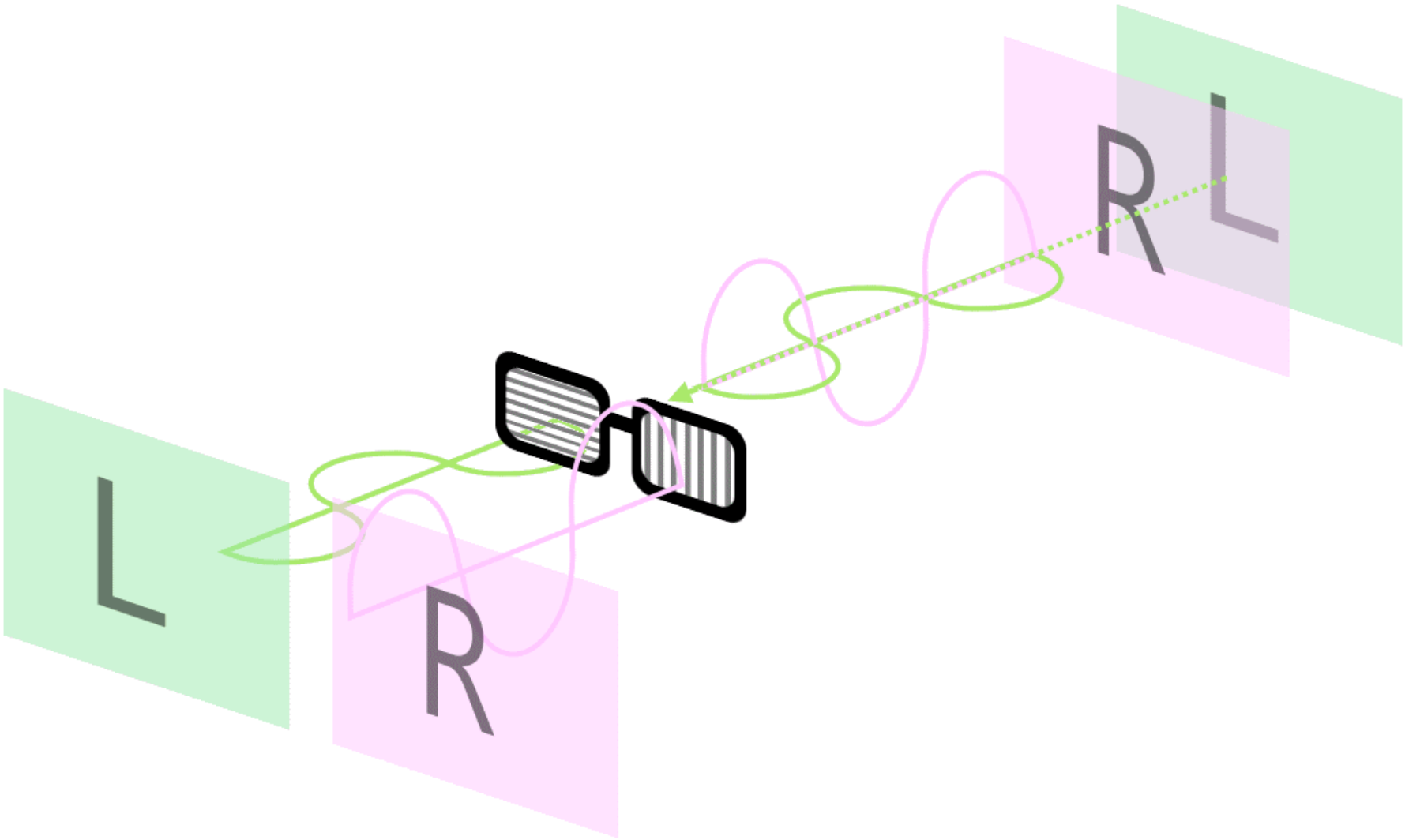
Anaglyph glasses

Pros: cheap (home-made)
Cons: without colors
bad 3D

Polarization glasses



Polarization glasses



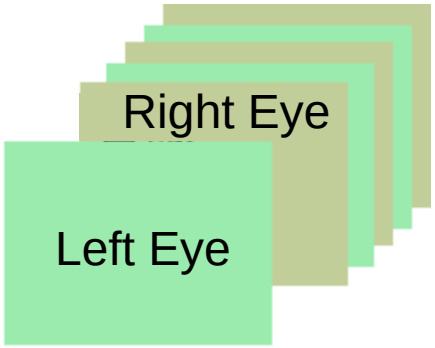
Polarization glasses

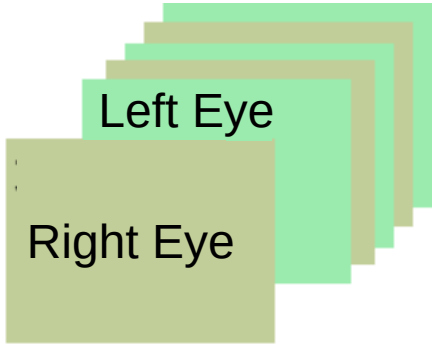
- How to display two polarized frames?

- Need accurate calibration so that the frames are aligned.
- Need non-depolarized screen.
- Cheaper glasses. Used in theater.

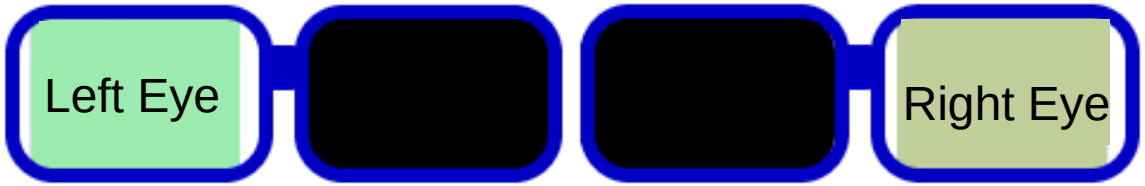
Shutter glasses

- Twice frequency (usually 120Hz).
- Liquid crystal. Needs to sync.
- Persistence of vision





Pros: good 3D
Cons: need to sync
darker
expensive
not good for multi-user



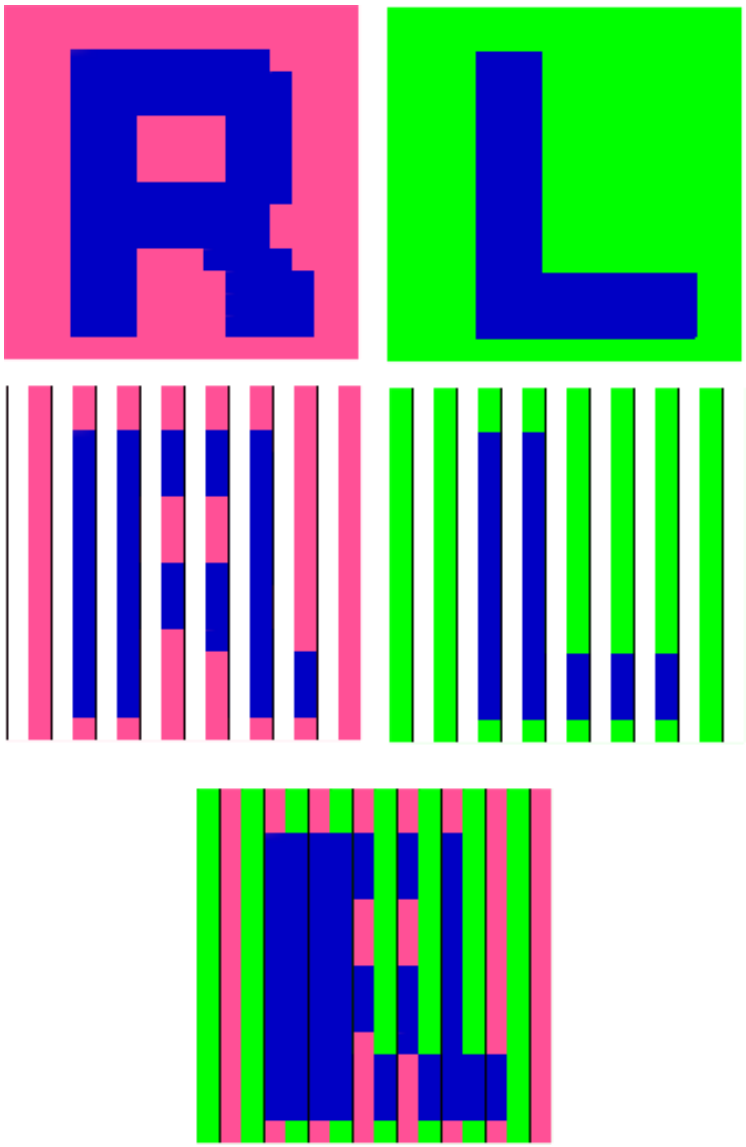
Head mounted displays

Pros: very good 3D
could be used with head trackers
Cons: expensive
heavy
closed
single-user

Autostereoscopic

- Control lights to radiate to specific directions by accurate optics calculation.
  - Spatial-multiplexed
  - Time-multiplexed

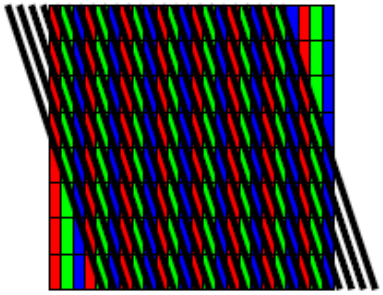
Spatial-multiplexed

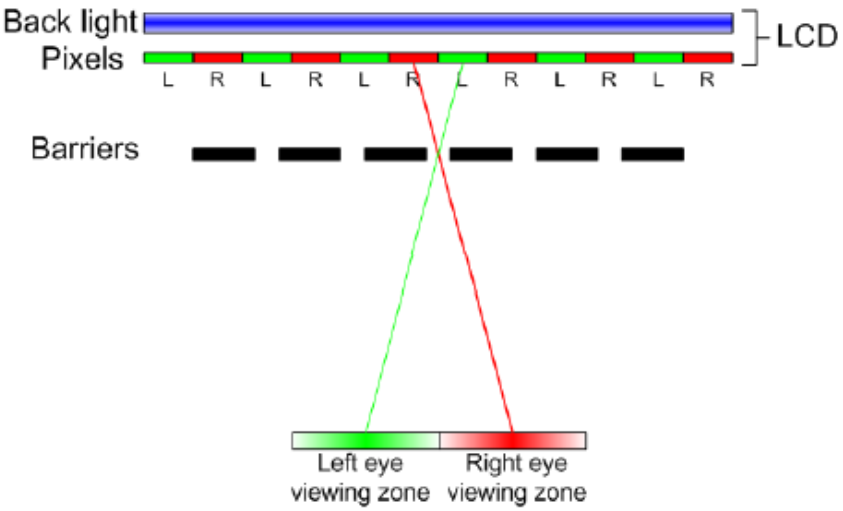


- The next question is how to let left eye see only the left image and right eye see only the right one.

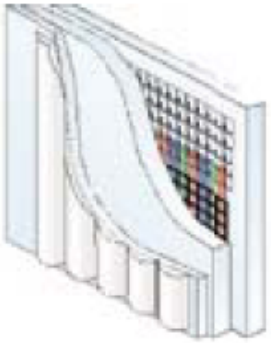
Autostereoscopic

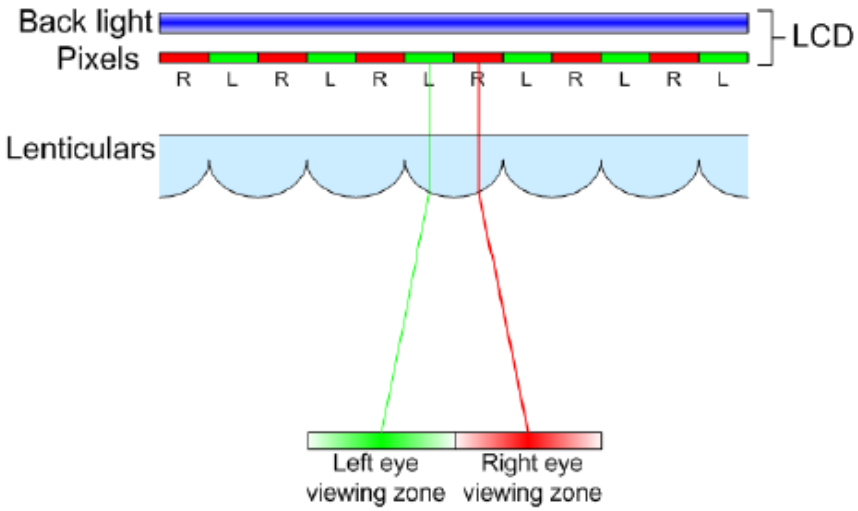
- Barriers(Slanted)



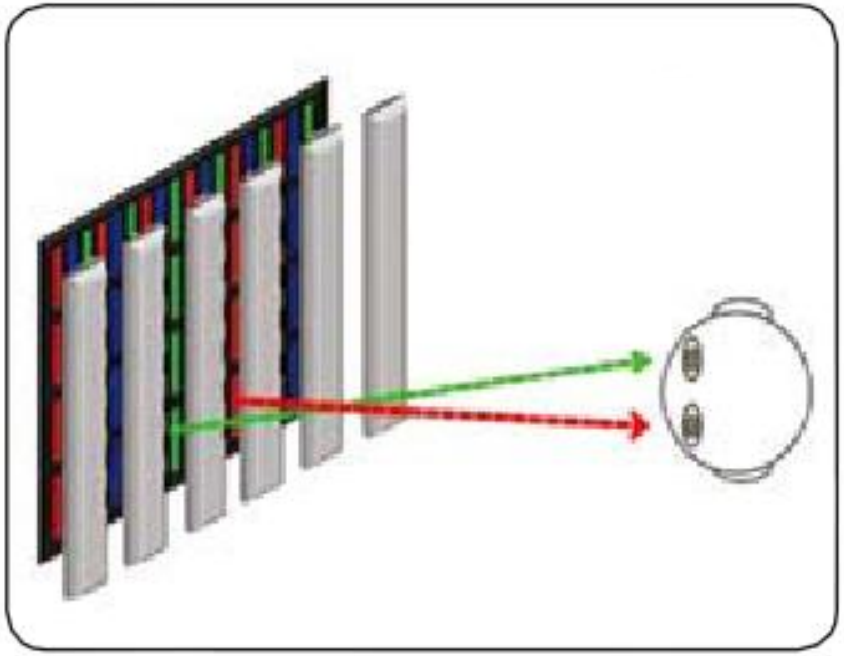


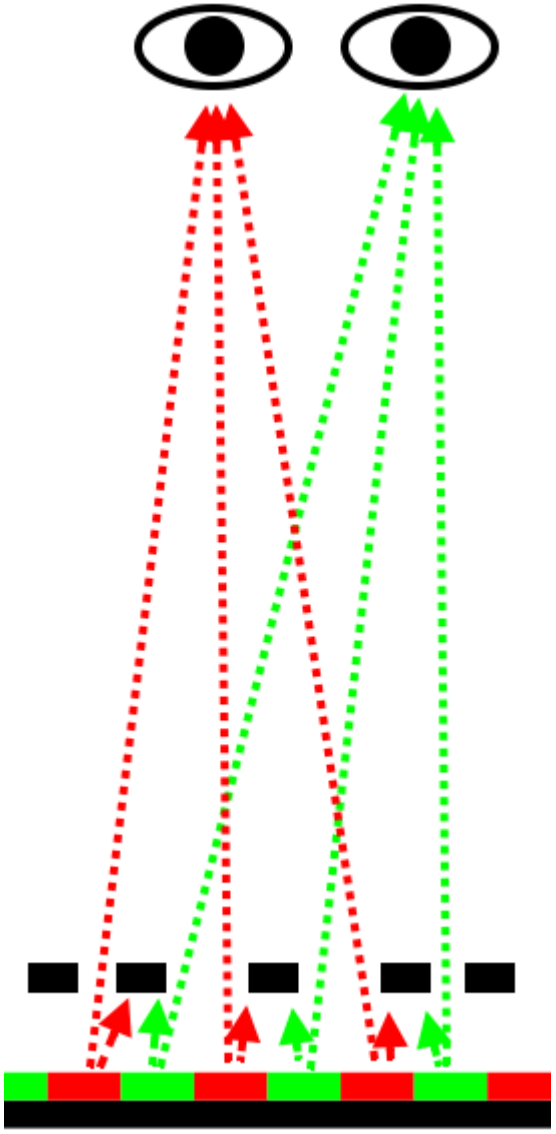
- Lenticulars





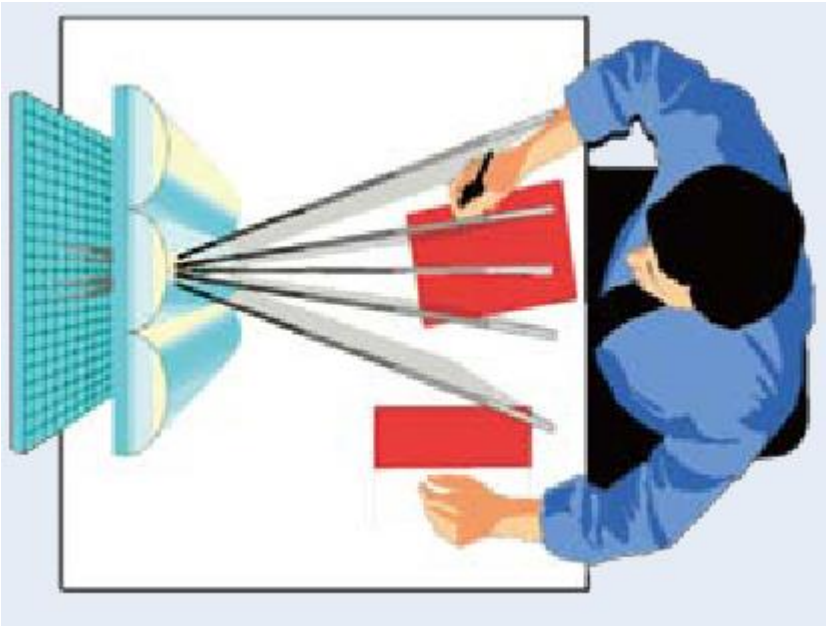
Barrier

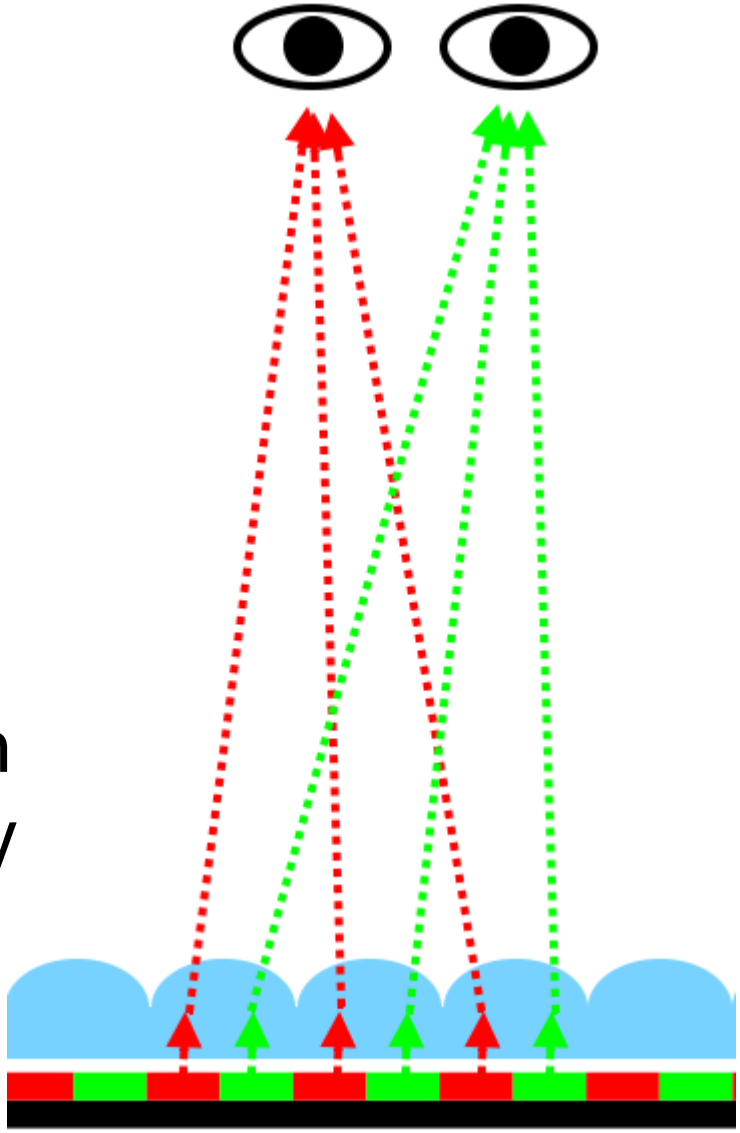




- LC barrier could switch between 2D and 3D display modes.

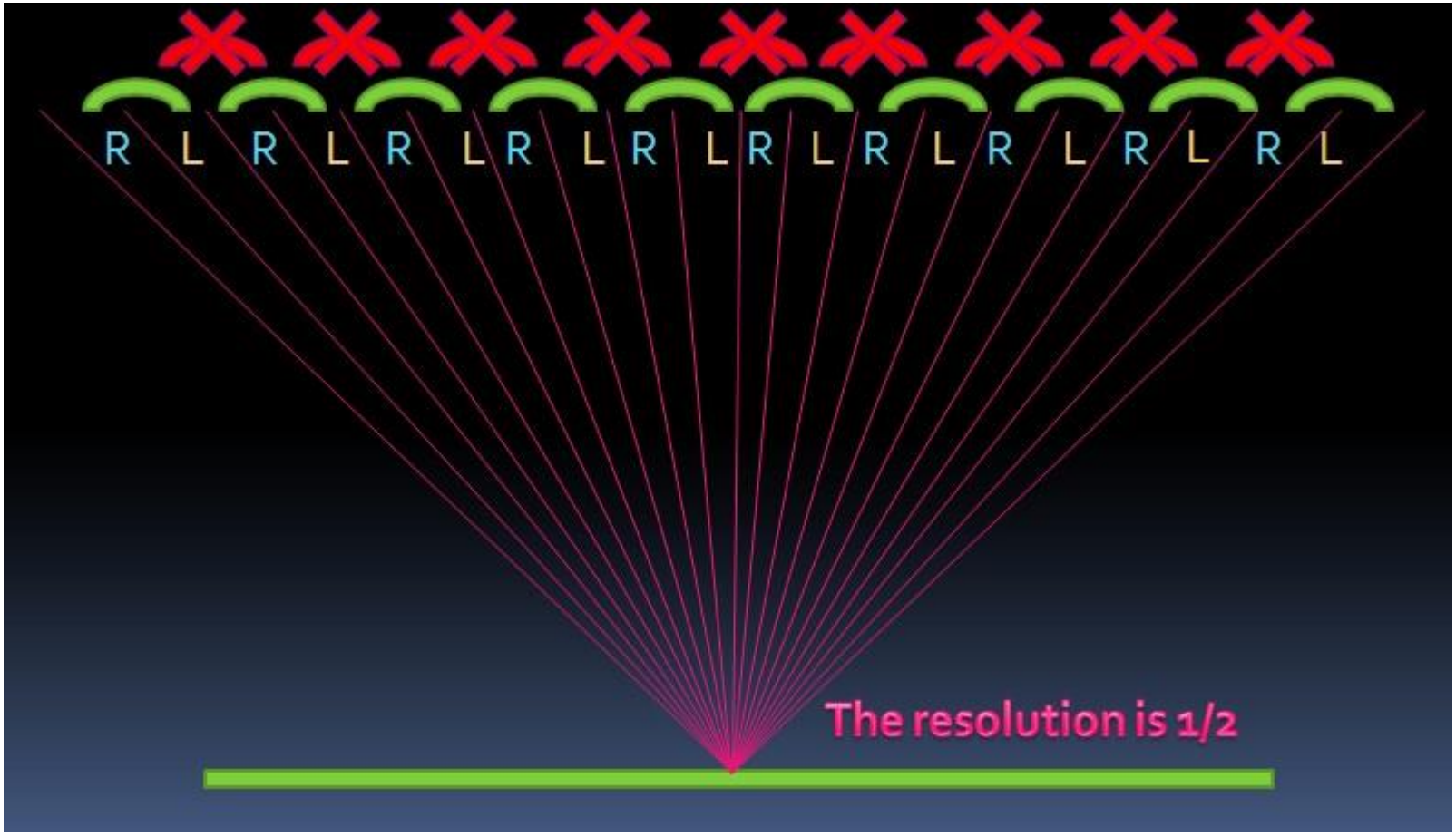
Lanticular



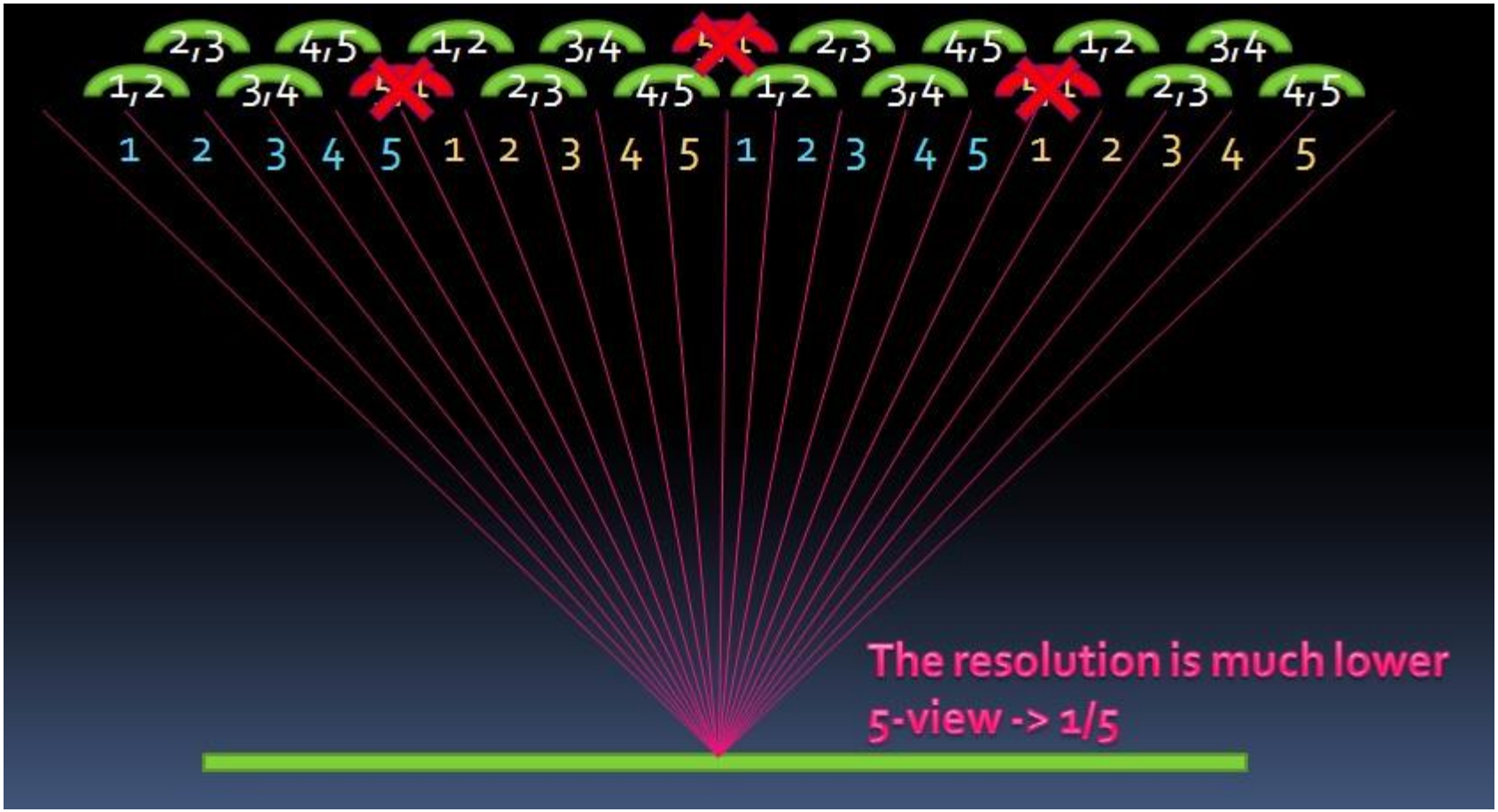


- It is also possible to switch between 2D and 3D display modes.

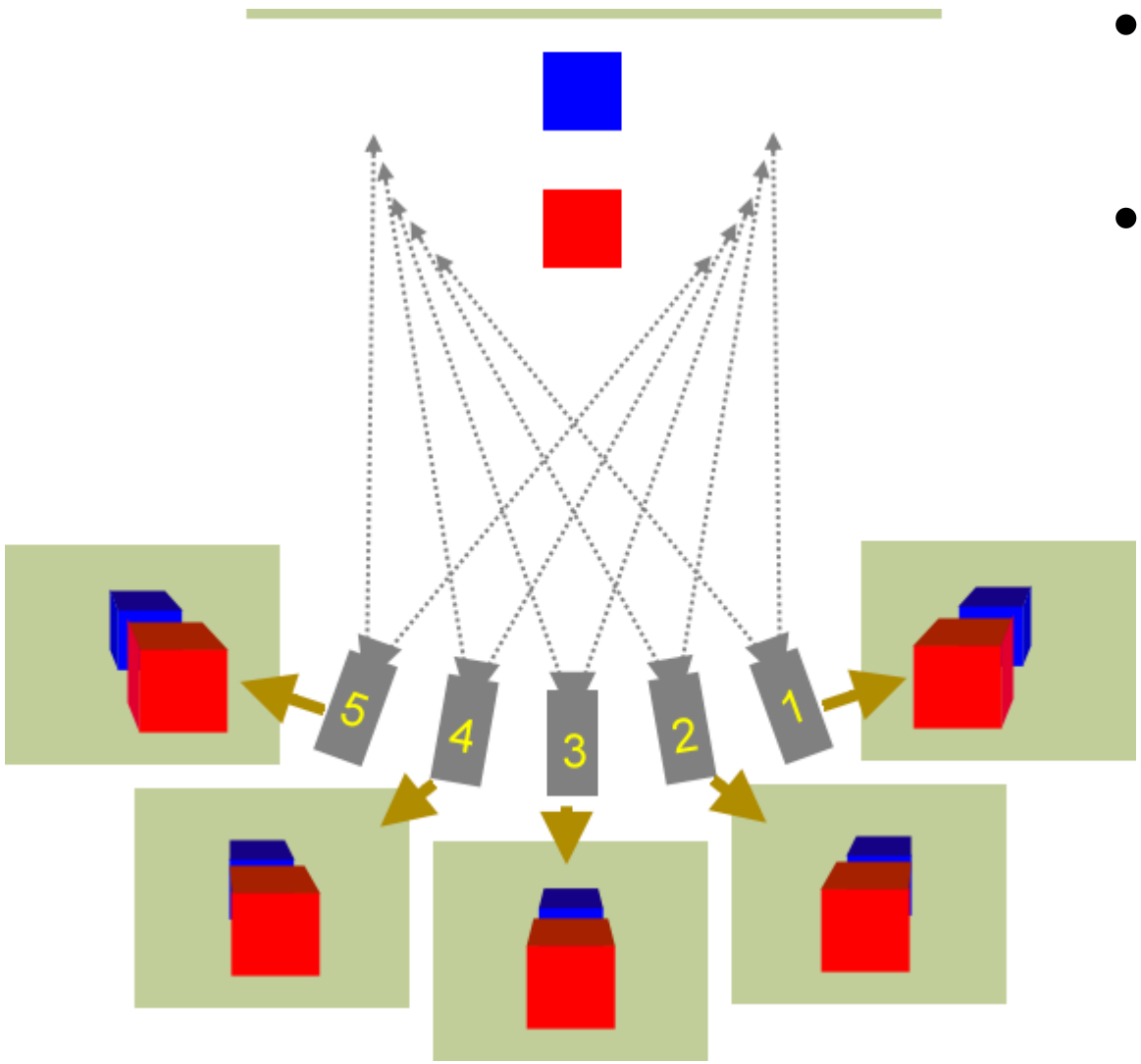
2-view



Multiple-view



Multiple-view



- Need more inputs.
- Reduced resolution.

Pros: no glasses
multi-user
Cons: location
bad 3D

Common 3D formats

- Side-by-side
- Multi-view
- 2D+Z

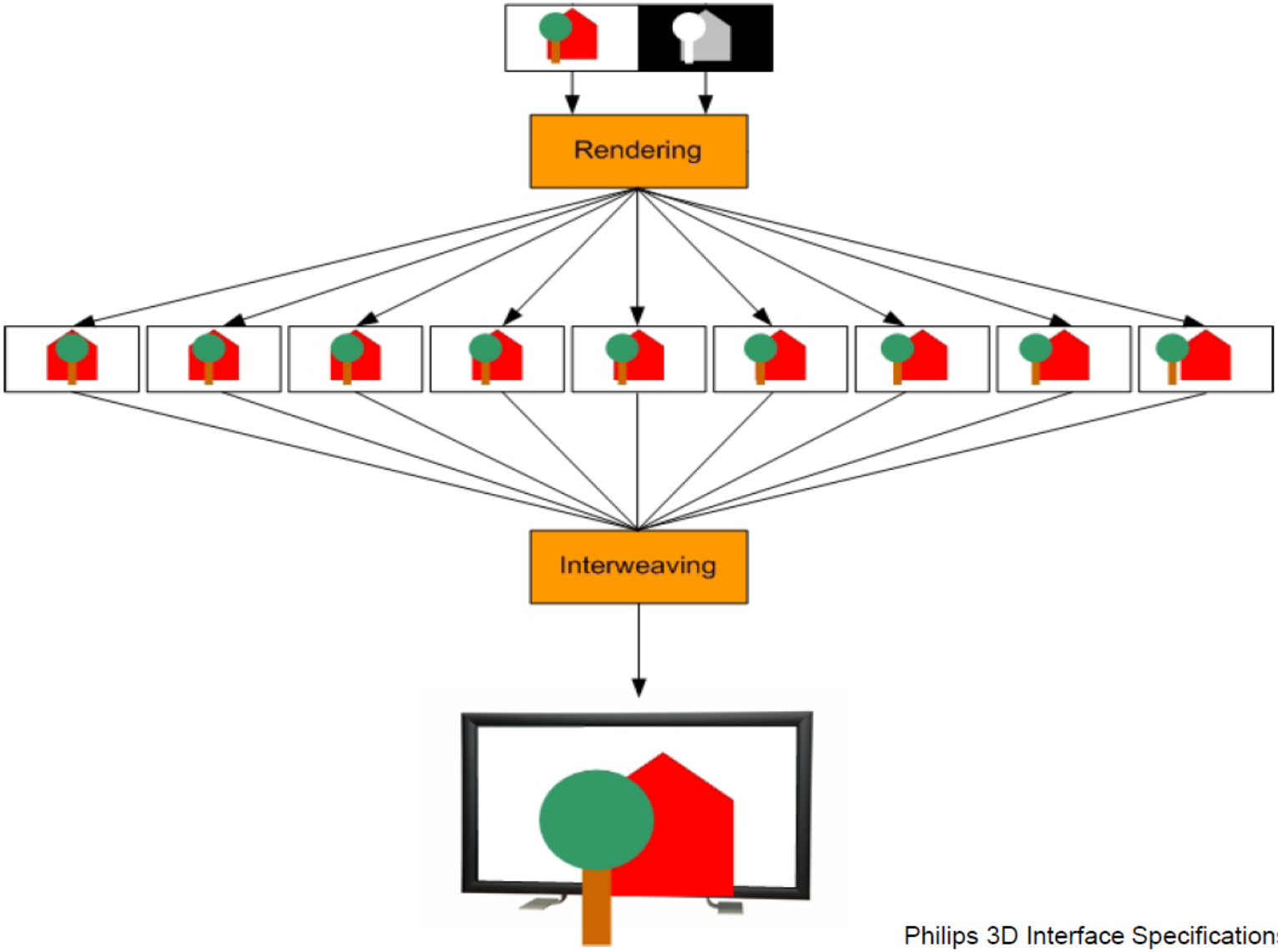
2-view

Side by Side

Multi-view

Newsight 8-View

2D+Z

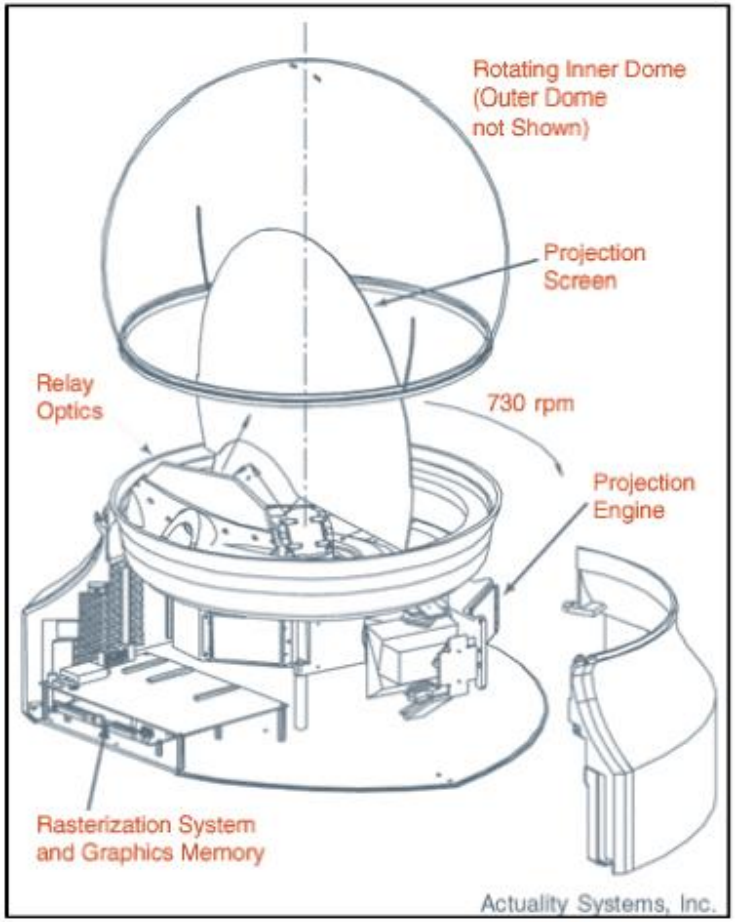


Philips 3D Interface Specifications White Paper

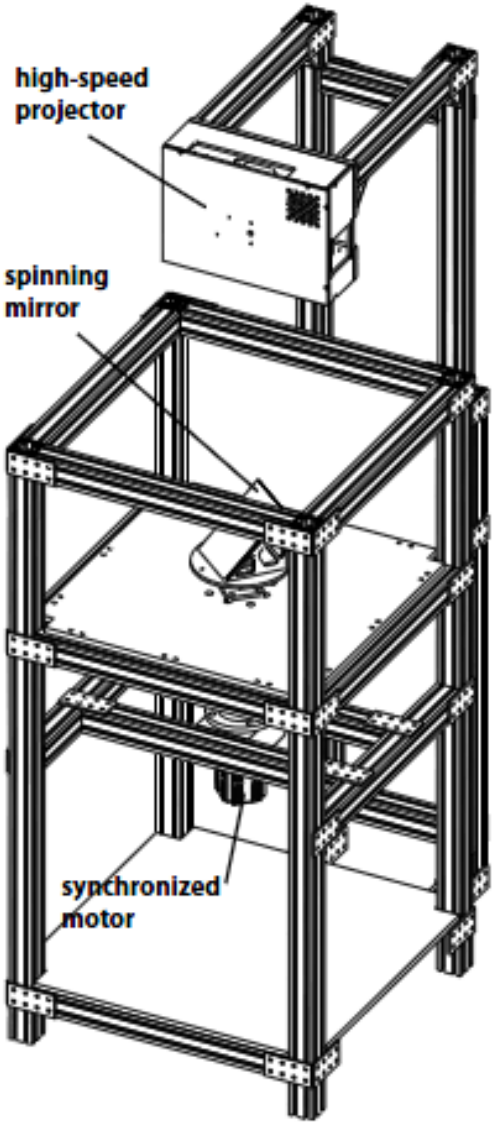
Volumetric displays

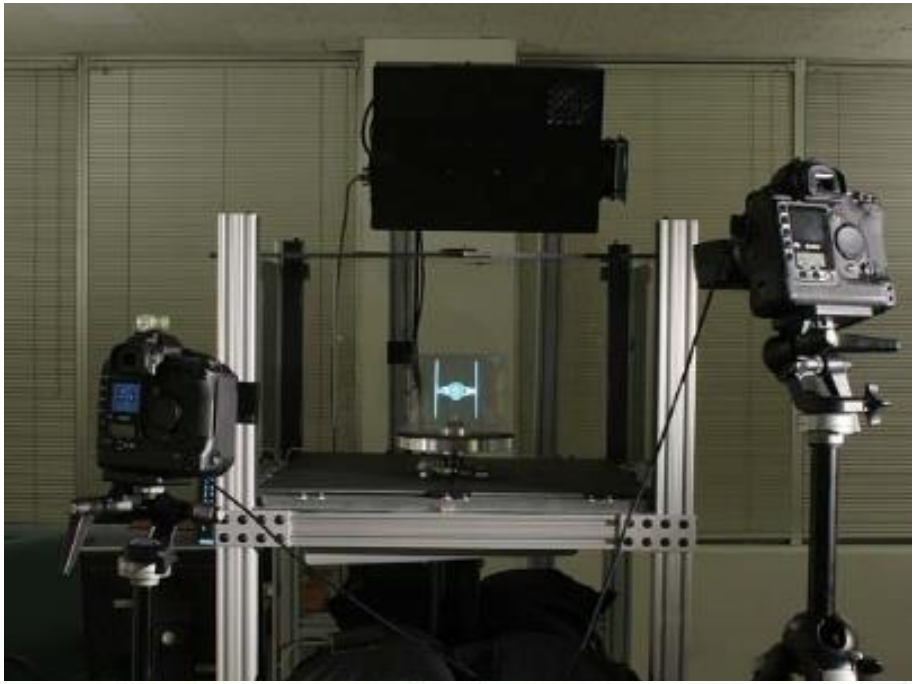
- Non-volumetric displays will make viewers fatigue after long viewing time because of inconsistency between focus and convergence.
- Volumetric displays will be better in this aspect but it is much more expensive and requires more data consumption (more views are required).
- Pros: good 3D, no glasses, multi-user
- Cons: often with limited size, suitable only for objects, not scenes

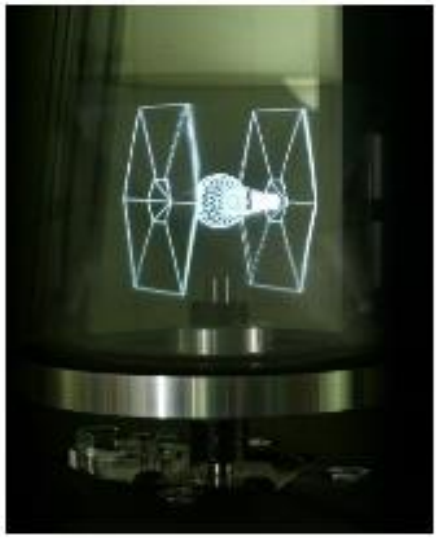
Actuality System



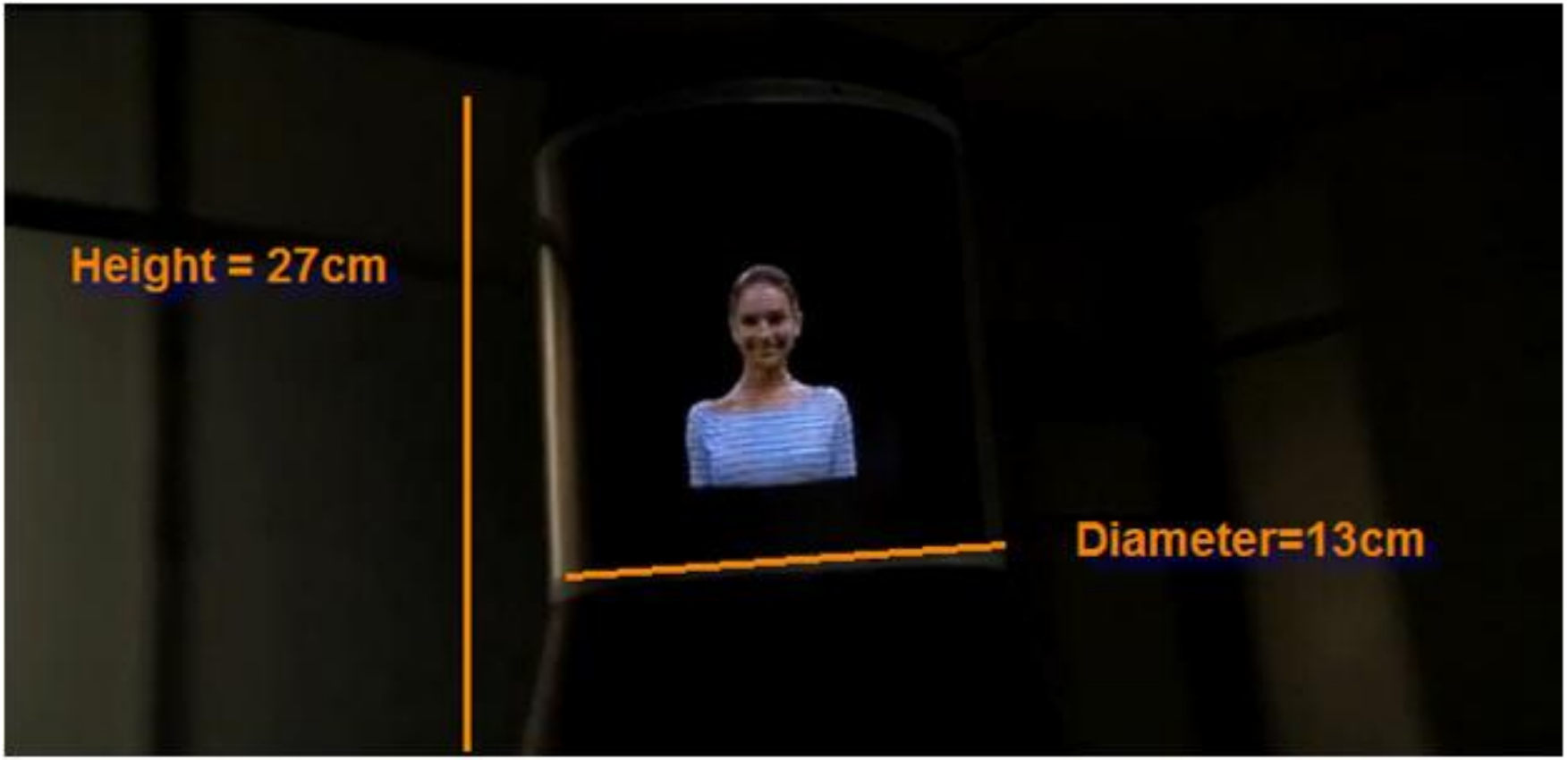
USC ICT







SONY RayModeler



The RayModeler is able to generate a true 3-D image with depth where a different proportionally correct view is visible from each side of the display.

Summary

- Many 3D displays will be produced in the coming years.
- Glass-equipped 3D display technology is very matured.
- Autostereoscopic displays need more time and will be used for advertisement first.
- 3D contents are the major bottleneck.
- But, 3D cameras are on the corner.

Next Time

- 3D cinematography
- Stereoscopic media post-processing