Stereoscopic Computer Graphics

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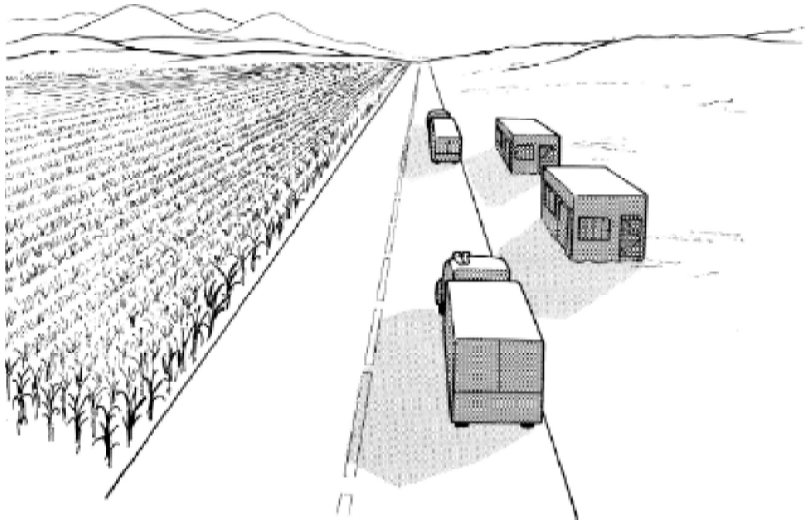
Overview

- 3D Depth Cues
- 3D Stereographics Terminology
- 3D Display

3D Depth Cues



Visual Depth Cues

- Perceiving "depth" with one eye closed

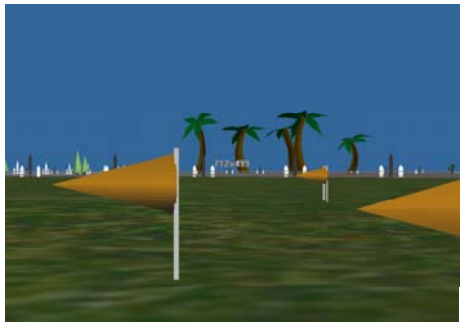
- Linear perspective
  - Objects get smaller the further away they are and parallel line converge in distance.
- Size of known objects
  - We expect certain object to be smaller than others.
- Detail (texture gradient)
  - Close objects appear in more detail, distant objects less.
- Occlusion (hidden surfaces)
  - An object that blocks another is assumed to be in the foreground.
- Lighting and Shadows
  - Closer objects are brighter, distant ones dimmer. Shadow is a form of occlusion.
- Relative motion (motion parallax due to head motion)
  - Objects further away seem to move more slowly than objects in the foreground.

Perspective

- The observance that parallel lines converge at a single vanishing point.
- Relies on the assumption that the object being viewed is constructed of parallel lines, such as most buildings.

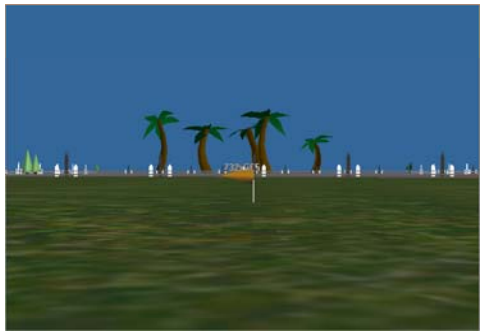
Size

- Compare the size of objects with our memory of similar objects to approximate how far away the object is from us.
- Comparing the size of objects with respect to other objects of the same type to determine the relative distance between objects.



Detail

- Our eyes cannot discern as much detail of a texture at a distance as compared with up close.
- Atmospheric effects, such as haze and fog, cause more distant objects to be visually less distinct.

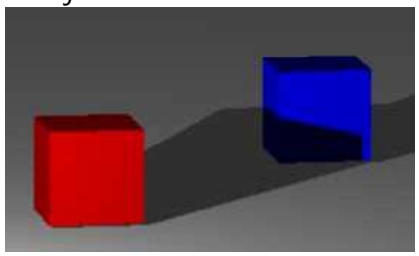


Occlusion

- An object occludes our view of another
- The strongest depth cue

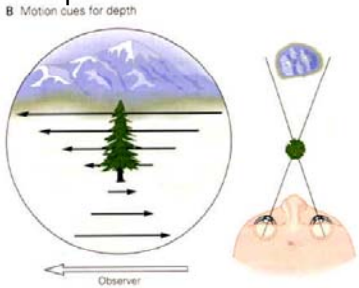
Lighting and Shadow

- Brighter objects are perceived as being closer.
- With one source of light, all shadows lie in same direction.
- The object covered by the shadow is perceived to be further away than the object in the light.
- A form of shading that indicate the positional relationship between two objects.



Motion Parallax

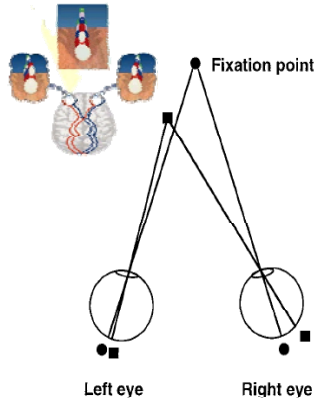
- As an observer moves, nearby objects appear to move rapidly while far objects appear to move slowly.
- Come from the parallax created by the changing relative position between the head and the object being observed.
- Generally more important than stereoscopy for VR.



Visual Depth Cues
- Using both eyes

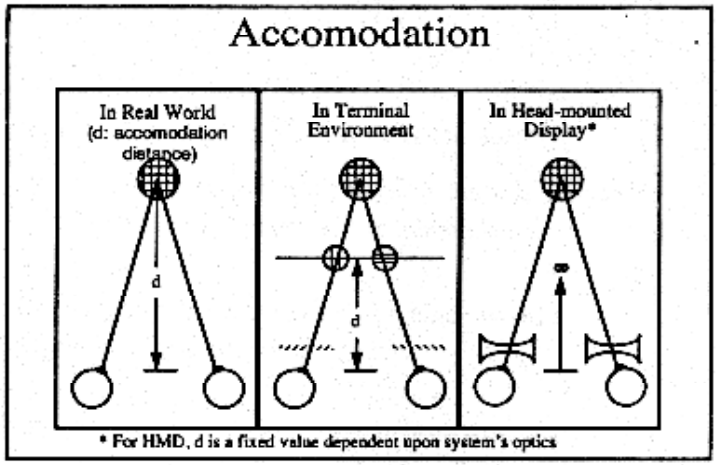
- Binocular cues: binocular disparity (stereopsis)
  - This is the difference in the images projected onto the back of the eye (and then onto the visual cortex) because the eyes are separated horizontally by the interocular distance.
- Oculomotor cues: accommodation & convergence
  - Based on information from muscles in the eye
  - Accommodation (focus)
    - This is the muscle tension needed to ***change the focal length*** of the eye lens in order to focus at a particular depth.
  - Convergence
    - This is the muscle tension required to ***rotate each eye*** so that it is facing the focal point.
  - Accommodation and Convergence work together (when eyes converge to a certain distance, automatically accommodates and vice versa)

Stereoscopy

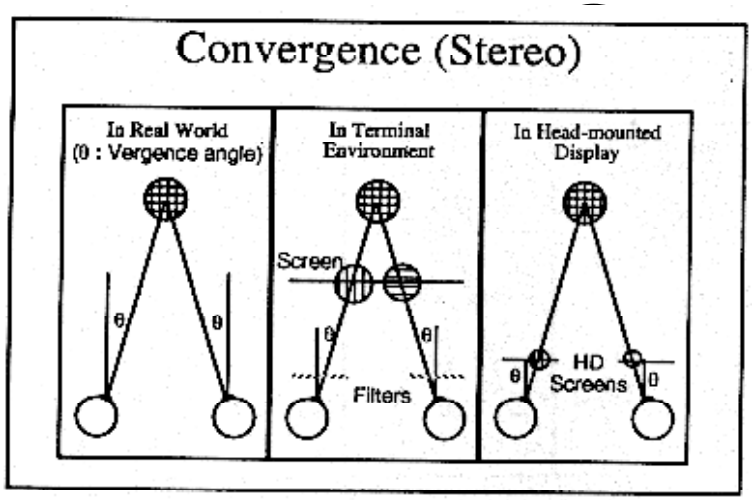


- Binocular vision occurs when two eyes look at the same thing at a slightly different angle, resulting in two slightly different images.
- The brain must match points between the two separate images seen by the two eyes.
- The slight difference between the viewpoints of your two eyes is called binocular disparity
- Stereopsis is depth perception due to binocular disparity
- Possibly 12% of people have no stereo vision or some problem with stereo vision.

Accommodation (focus)



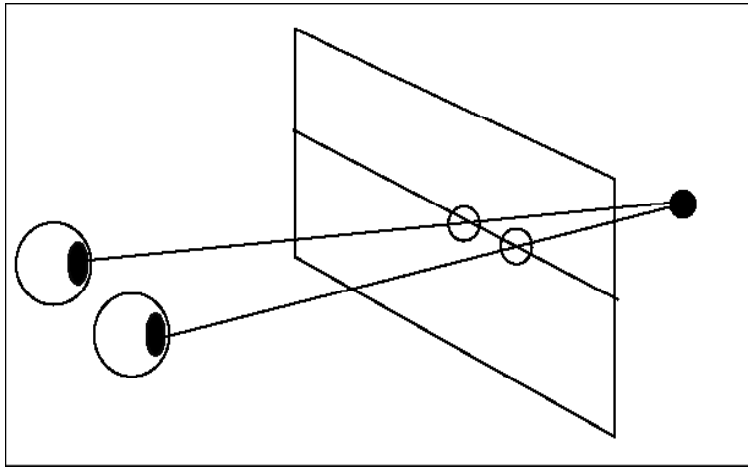
Convergence



Some Terminology

- Horizontal Parallax (Binocular Disparity)
  - When the retinal images of an object fall on disparate points on the two retinas, these points differ only in their horizontal position.
  - The value given by R – L
- Stereo Window (Stereo Plane)
  - The point at which there is no difference in parallax between the two eye views
  - Usually at the same depth as the monitor screen or the projection surface.
- Homologous Points
  - Points which correspond to each other in the separate eye views.
- Vertical Displacement
  - Vertical parallax between homologous points relative to the line that the two eyes form.

Homologous Points



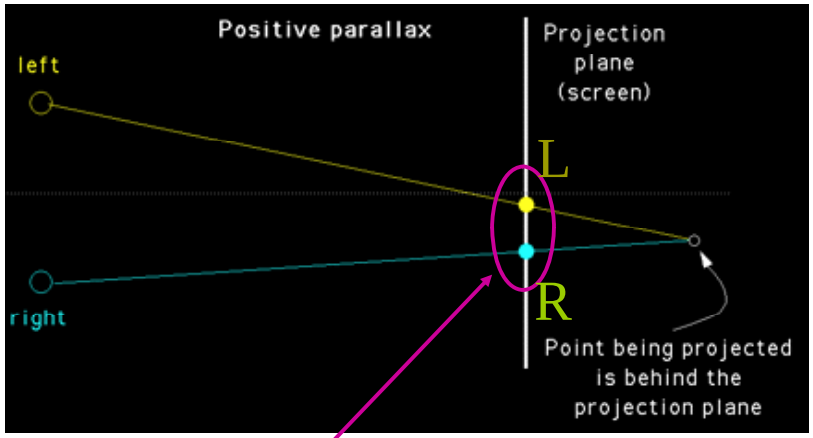
Some Terminology

- Interocular Distance
  - The distance between the left and right eyes, usually about 2.5 inches (i.e., 6.5 cm)
- Hypostereo/Giantism
  - Decreasing the distance between the left and right eyes to show stereoscopic detail on small items
- Hyperstereo/Lilliputism
  - Increasing the distance between the left and right eyes to show stereoscopic detail in large scenes
- Interocular Crosstalk (Ghosting)
  - Each eye should only see it's view but sometimes it can see part of the other eye view as well. This is distracting and causes eye fatigue.

Some Terminology

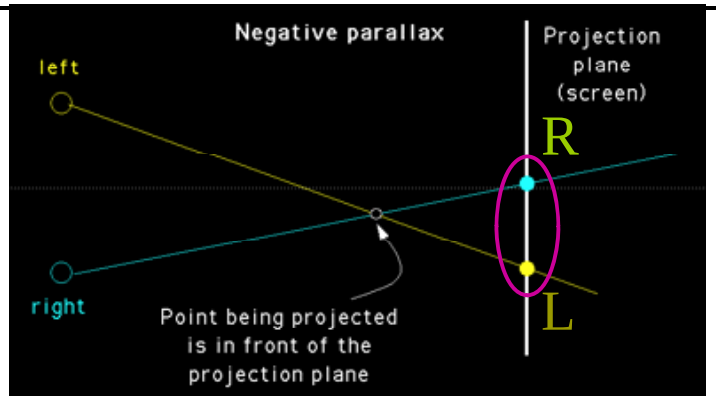
- Positive Parallax
  - The point lies behind the stereo window (On the opposite side from the observer)
- Negative Parallax
  - The point lies in front of the stereo window (On the same side as the observer)
- Zero Parallax
  - The point is at the same depth as the stereo window (Both eyes see the same image)

Positive Parallax
Accommodation-convergence mismatch



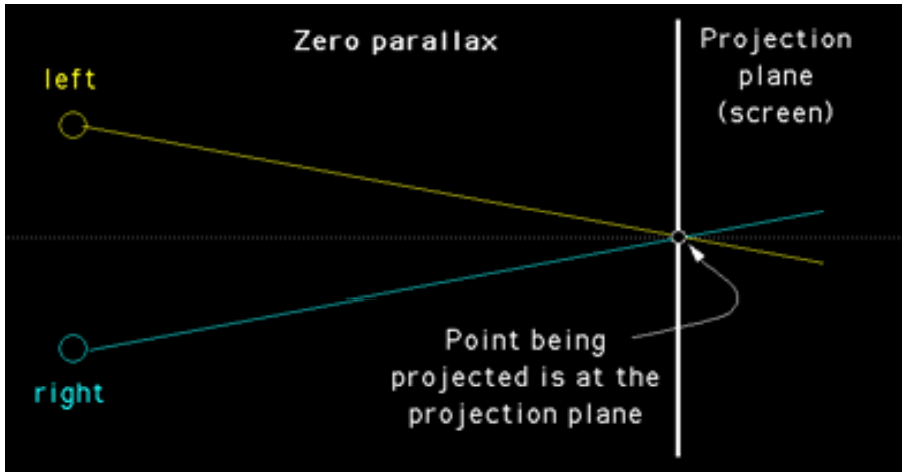
The left and right eye images projected on the screen

Negative Parallax
Accommodation-convergence mismatch

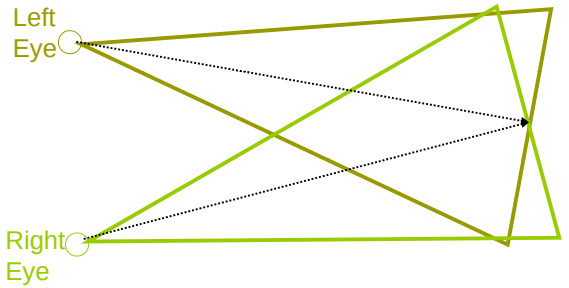


- If Objects are too close in front of the projection plane, negative parallax will increase.
- If negative parallax is wider than eye separation, then result is pain.

Zero Parallax
When the object is actually on the screen

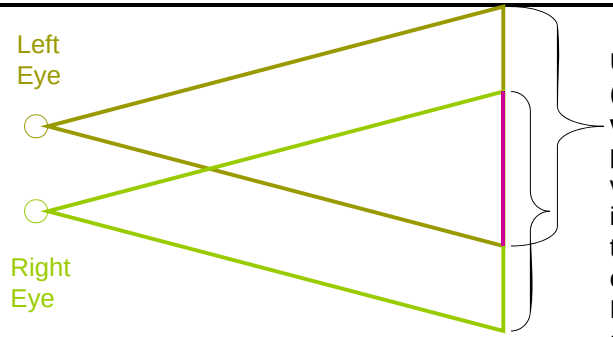


Stereo Approximation



Viewing a point in a scene from two difference camera positions produces differing view planes

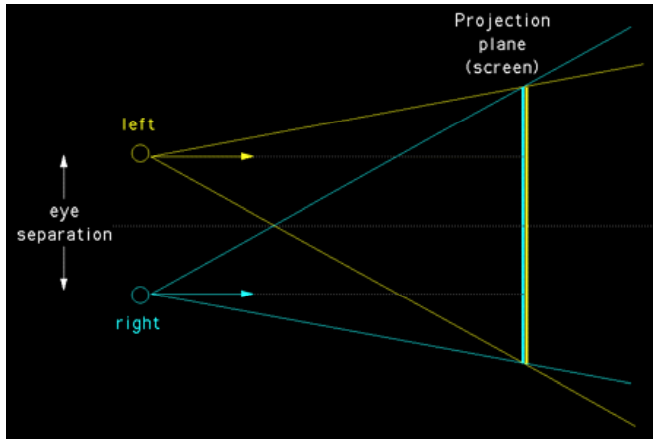
Stereo Approximation



Using parallel views (i.e. **symmetric view frustums)** produces a single view plane, but images must be trimmed to area of overlap - Projection Planes are not the same

- Some software (e.g. Blitz3D) does not have an easy way (yet) to create asymmetric view frustums.
- There is potential for eye discomfort for objects that are too close because an object may appear to be cut off at the edges for one of the eyes.
- Enlarging eye separation makes the problem worse.

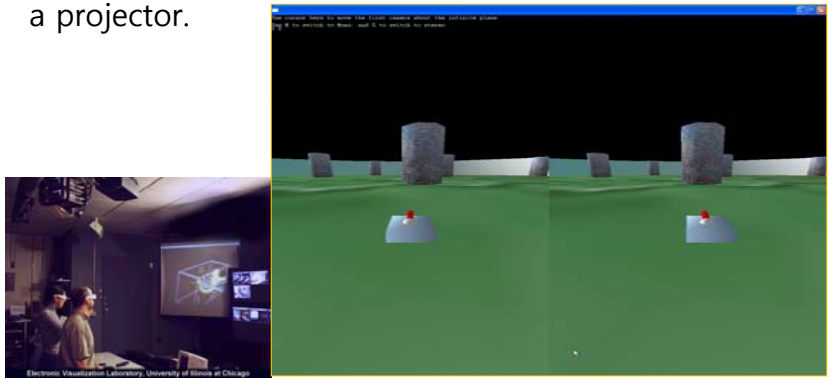
Correct Stereo Computer Graphics



The correct approach using **parallel views and asymmetric view frustrum** produces a single viewplane and overlapped image

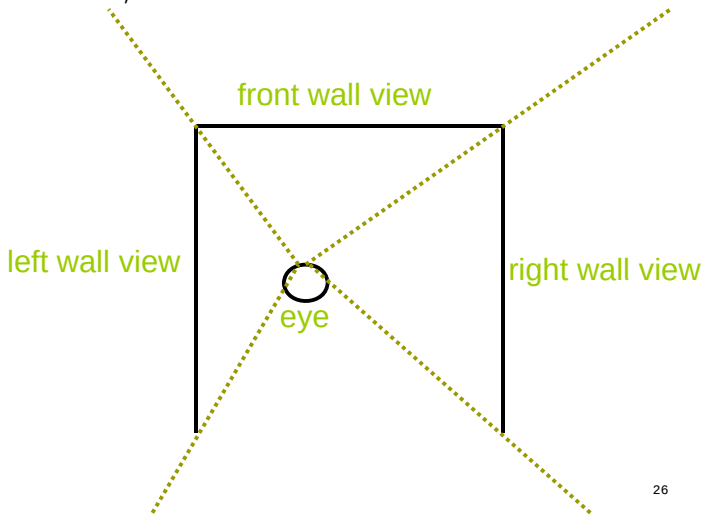
Stereo Images on the GeoWall

- Creates 1 wide window 2048x768 and creates 2 viewports (1 for left eye image, 1 for right eye image)
- Each viewport goes to 1 of the graphics card's outputs to a projector.

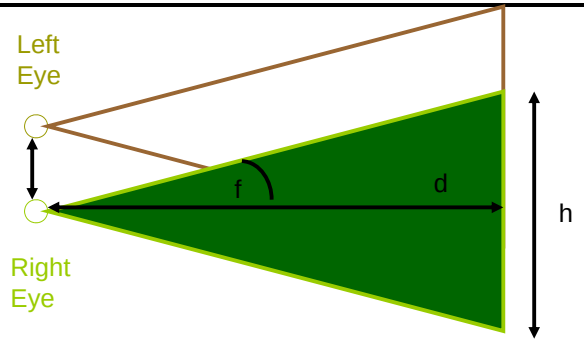


Off-axis Perspective Projection in a CAVE

- In CAVEs, the view frustum will often fall off center.



Making the virtual world look true to size



- Set camera properties to be the same as real world properties:
  - Set user's distance to screen (i.e. focal length d)
  - Measure the screen's height (h)
  - Compute the field of view (f = 2*atan(h/2d))
  - Use real world eye separation distance (2.5 inches)

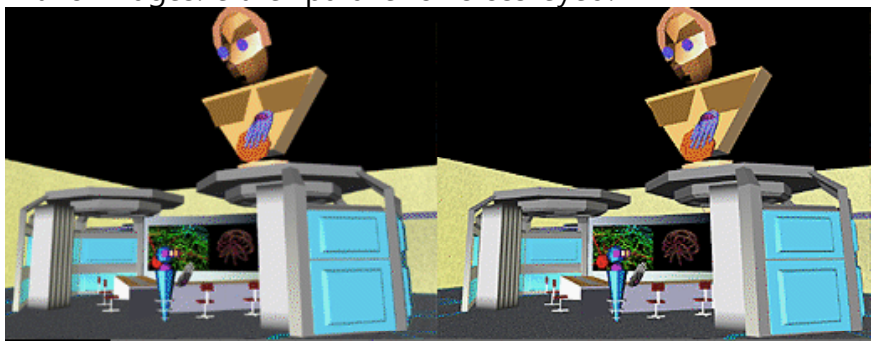
How to Generate Stereo Images

Present a distinct image to each eye:

- Free-viewing
- Optics (lenses)
- Chromadepth
- Pulfrich Effect
- Anaglyph (color)
- Polarization
- Active Shuttering
- Autostereo

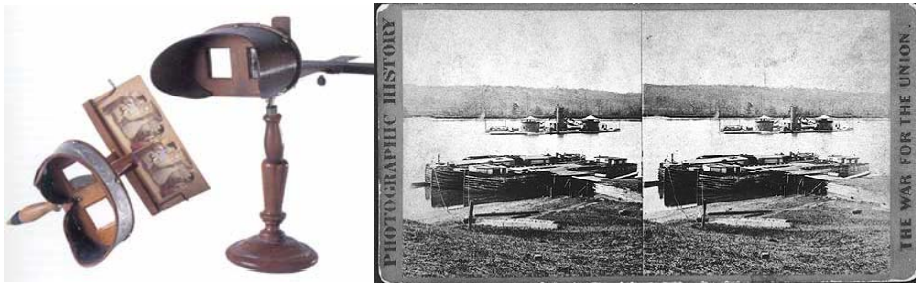
Free-viewing

- Two slightly different images are displayed next to each other.
- The viewer must focus his or her eyes properly to fuse the two images: either parallel or cross-eyed.



Optics

- Use lenses and physical separation, present a separate image to each eye.



Stereoscope, invented by Charles Wheatstone in early 1800s

Optics

Viewmaster

Slidemaster

Optics

HMD

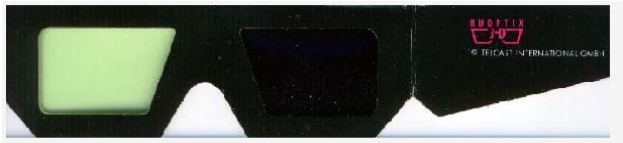
BOOM

Chromadepth

- Special filters that cause different colors to appear at different depths.
- Red objects appear close; blue objects appear distant.

Pulfrich Effect

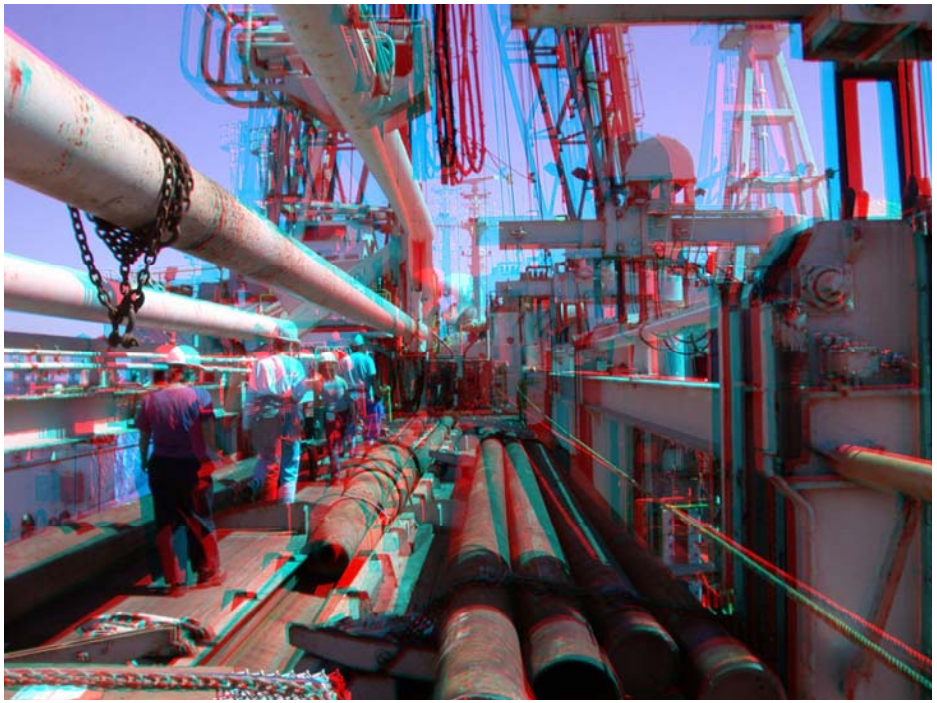
- Physiological effect discovered by astronomer, Carl Pulfrich.
- Pulfrich effect glass have one dark lens and one clear lens.
- Images viewed through a darkened lens reach the brain **slower** than those viewed through a clear lens.
- When something moves across the visual field, the brain fuses **two images from slightly different times**. Motion is thus converted into stereo parallax.



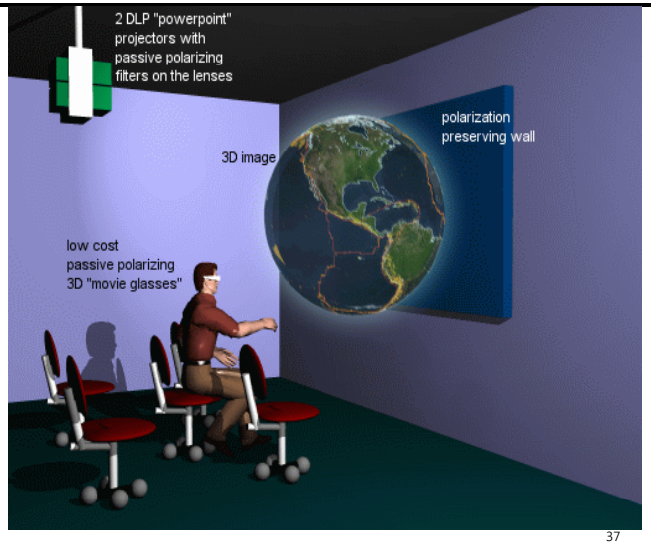
Pulfrich glasses as used on broadcast-TV

Anaglyph

- Colored filtered are used – one eye sees just red elements, other eye sees blue (or green or cyan) elements.
- The colored lenses make one image more visible to one of your eyes and less visible to your other eye.



Passive Polarization



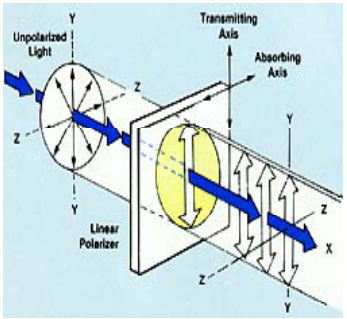
GeoWall

Passive Polarization

IDesk4 – Linear Polarization

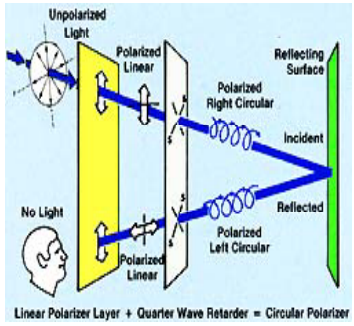
IDesk4 – Circular Polarization

Linear Polarization



- A single "ray" of light has a particular polarization direction, perpendicular to direction of propagation.
- Ordinary light usually is polarized equally in all directions.
- A polarizing filter allows only light polarized a certain direction to pass through
- Less expensive.
- Problem: tilting the viewer's head affects filtering and hurts stereo effect.

Circular Polarization



- Combining a linear polarizer and a quarter-wave retarder produces circular polarization.
- Circular polarization can be clockwise or counter-clockwise.
- Circular polarization is immune to the "head-tilt problem."
- Works better because light is circularly polarized.
- Problem: Many project screen materials de-polarize light; mirrors can also de-polarize light, at larger angles of reflection; LCD projects polarize light internally (green one way, red & blue another way)

Active Shutter Glasses

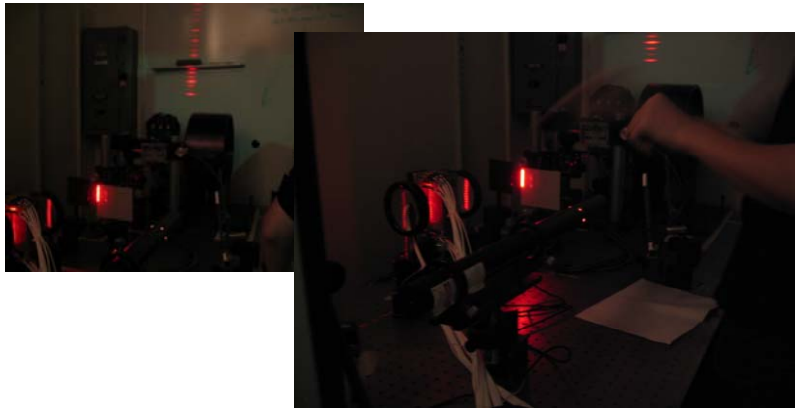
- Glasses have liquid crystal lenses which can be darkened & cleared rapidly - at any time one lens is clear and one is dark.
- Glasses are synchronized with video display - one eye sees odd frames, other eye sees even frames.
- Requires fast video refresh rate (> 90Hz) to prevent flicker.
- LCD projects are not capable of high frequencies. Affordable DLP projectors not programmed to support high frequencies.

Auto-stereoscopic

- Glass-free stereo
  - Image broken into sets of vertical strips. Each set is a different eye-view
- Autostereoscopic
  - Parallax barrier: Barrier strip (PHSCologram, Synthagram, etc) separate layer with strips that block all but one image from any viewpoint
  - Lenticular: lens like stripes
  - Lenslet: Integral photograph or integram
- 3D displays
  - Hologram
  - Volumetric
  - Stereoscopic: Active stereo, Passive stereo, Autostereoscopic

Hologram

- MARK-II @ MIT Media Lab

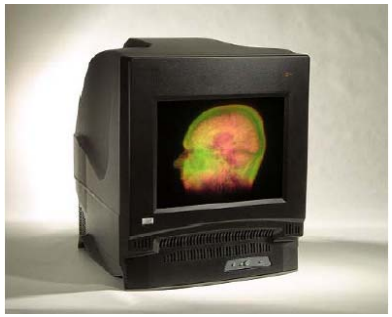


Volumetric Display

- Spinning Screen Display

Actuality Systems

- Slice-Stacking Display



LightSpace Tech

Autostereo 3D Display

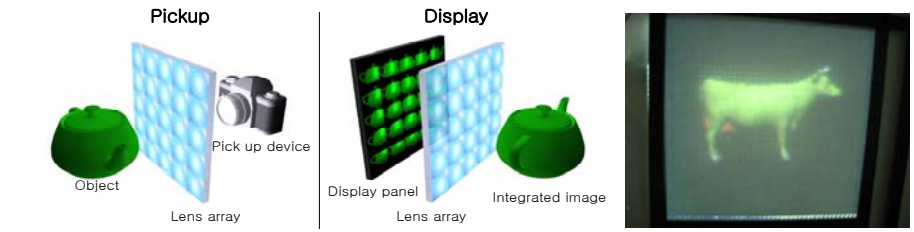
Pavonine, 17"/19" Dimen
-Backlight switchable barrier

Philips, 42" WOWvx 42-3D6C01
-Lenticular, support for multiusers

Sharp, Actius RD3D Notebook
-Backlight switchable barrier

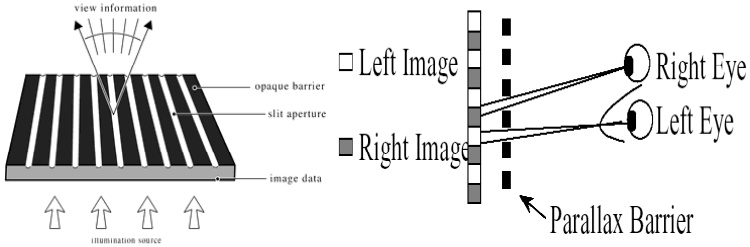
Autostereo 3D Display

- Integral-Imaging System



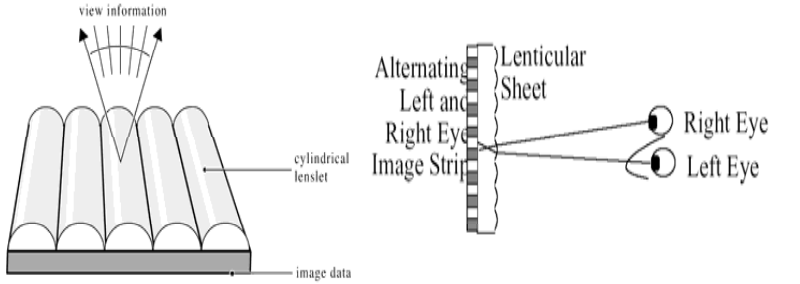
Parallax Barrier

- A vertical slit plat placed in front of a specially prepared image made of strips of alternating left and right eye views



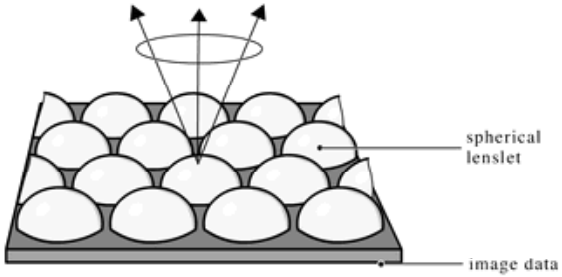
Lenticular

- Need no special viewing equipment
- Made from strips of cylindrical lenses



Lenslet

- Uses spherical lenses instead of cylindrical ones to present horizontally and vertically varying directional information, thus producing a full parallax image



Reference

- http://www.mlab.uiah.fi/nmc/stereo/masters/eng/vocabulary.html
- http://www.3dnshop.com/dic/list.php
- http://local.wasp.uwa.edu.au/~pbourke/projection/caev/
- http://web.cs.wpi.edu/~matt/courses/cs563/talks/stereohtml/stereo.html
- James Helman SIGGRAPH'93 Applied VR course notes
- Dennis Proffitts SIGGRAPH'94 Developing Advanced VR Applications course notes
- Lou Harrison SIGGRAPH'97 Stereo Computer Graphics for Virtual Reality notes
- http://www.siggraph.org/education/materials/HyperVis/virtual.env/percept.iss/percept.htm
- http://www.wmin.ac.uk/ITRG/IS/DPI/HIW/Human%20Visual%20System.pdf
- http://web.media.mit.edu/~halazar/autostereo/autostereo.html