Display systems

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Overview

- Display technologies
  - Current
  - In development
- Various VR display systems
  - Non-immersive, semi-immersive and immersive

Often a critical factor

- VEs engage visual senses above others
  - Quality of display may determine quality of system
- Projected or screen-based?
- Size
  - Related to immersive v not
- Speed
  - Will they respond to interaction?
- 2D or 3D?
  - Still mostly 2D pretending to be 3D
  - But new technologies very desirable

More display parameters

- Resolution
  - Size and distance-related
- Colour
  - Use differently-coloured pixels next to each other
- Brightness
- Contrast
- Refresh rate
  - Interactivity depends on this
- Sensitivity to viewing angle

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Technologies

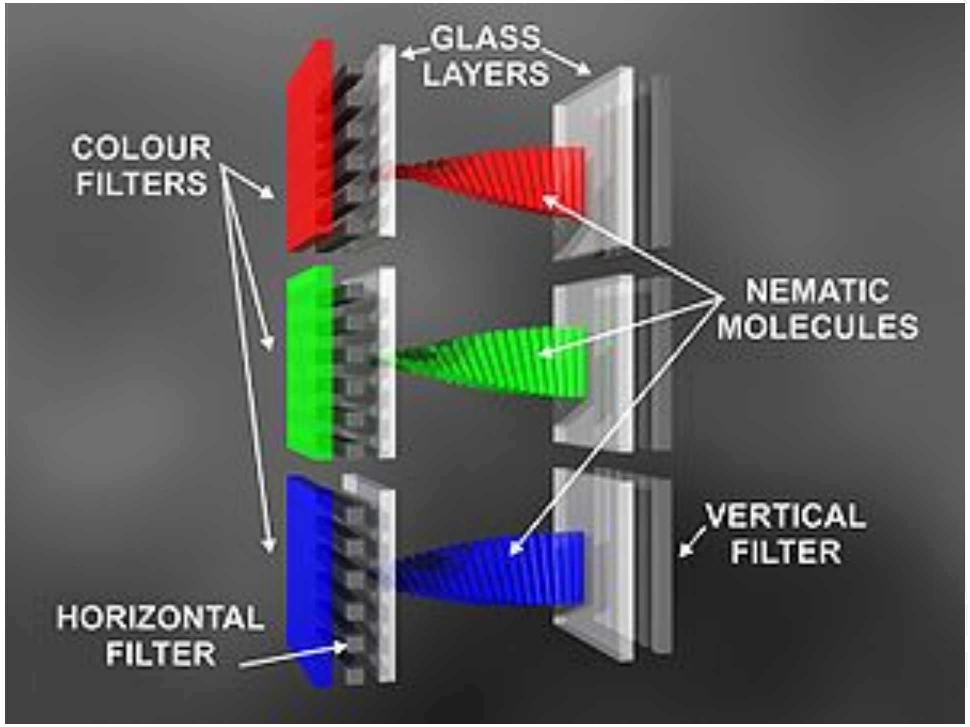
- Liquid crystal display - LCD
  - Active and passive
- CRT (Cathode Ray Tube)
- Digital Light Processor
- Auto-stereoscopic
- Virtual Retina Display

LCDs

- Made of small flat chips
  - Transparency properties change when voltage applied
- Elements in an $n x m$ array
  - LCD matrix
- Level of voltage controls gray levels
- Elements do not emit light
  - LCD matrix is backlit

LCDs cont

- Colour via filters in front of each LCD element
  - Impacts brightness
  - Usually black space between pixels to separate filters
- Hard to make individual LCD pixels very small
  - Impacts resolution
- Image quality depends on viewing angle.



LCD types

- Passive
  - Cycle through LCD matrix applying required voltage to each element
  - Once aligned with the electric field the molecules in the LCD hold their alignment for a short time
- Active
  - Each element contains a small transistor that maintains the voltage until the next refresh cycle.
  - Higher contrast and much faster response than passive LCD

Resolution

- Often quoted as separate colour elements not number of RGB triads
  - Example: 320 horizontal by 240 vertical elements = 76,800 elements
  - Equivalent to 76,800/3 = 25,600 RGB pixels
  - So "Pixel Resolution" is c 185 by 139 *($320/\sqrt{3}$, $240/\sqrt{3}$)*

Screen-based displays

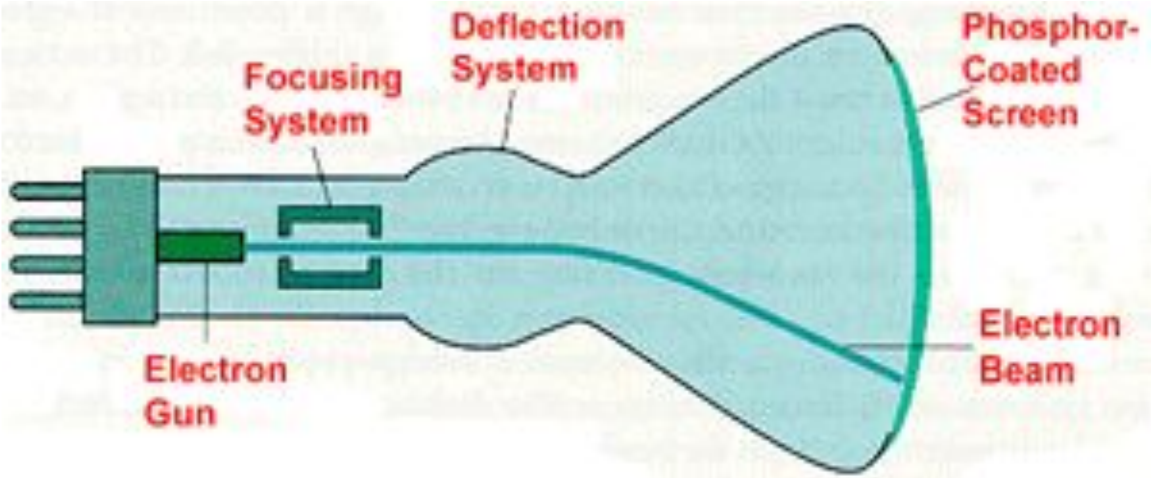
- Limited in size
  - LCD max = 108 ins
  - Plasma max = 103 ins; non interactive
    - Problems with green phosphor latency limiting update rate
- Limited in resolution
- Thin & lightweight
  - Flexible displays in development

  http://en.wikipedia.org/wiki/Flexible_display

Projected displays

- Use bright CRT or LCD screens to generate an image
  - sent through an optical system to focus on (usually) large screen.
- Full colour obtained via separate monochromatic projector for each of R,G,& B colour channels

CRT projector



Front v Back projection

- Front projection:
  - Can cast awkward shadows, especially if you get too close
  - Projectors typically high up and hard to access
  - Makes best use of available light
- Back projection:
  - Expensive translucent screen
  - Needs more space
  - Loses light: brighter displays needed

Projector pros & cons

- Very large screens
  - Large FoV
  - Can be shared by many - supports cooperative working
- BUT image quality can be fuzzy
  - Light is lost: dimmer than monitor displays
  - Sensitive to ambient light.
  - Delicate optical alignment, at least with CRTs

CRT pros and cons

- Typically: 3CRT's + lens per projector
  - Liquid cooled internally
  - Hot; Noisy (cooling); Consume a lot of power; Fragile
- Analogue devices
  - Need frequent calibration; Phosphor decays; Not particularly bright
- Good refresh rate (essential for stereo)
- Very good contrast (20,000:1)
- Can distort the image as necessary to get rectangular display

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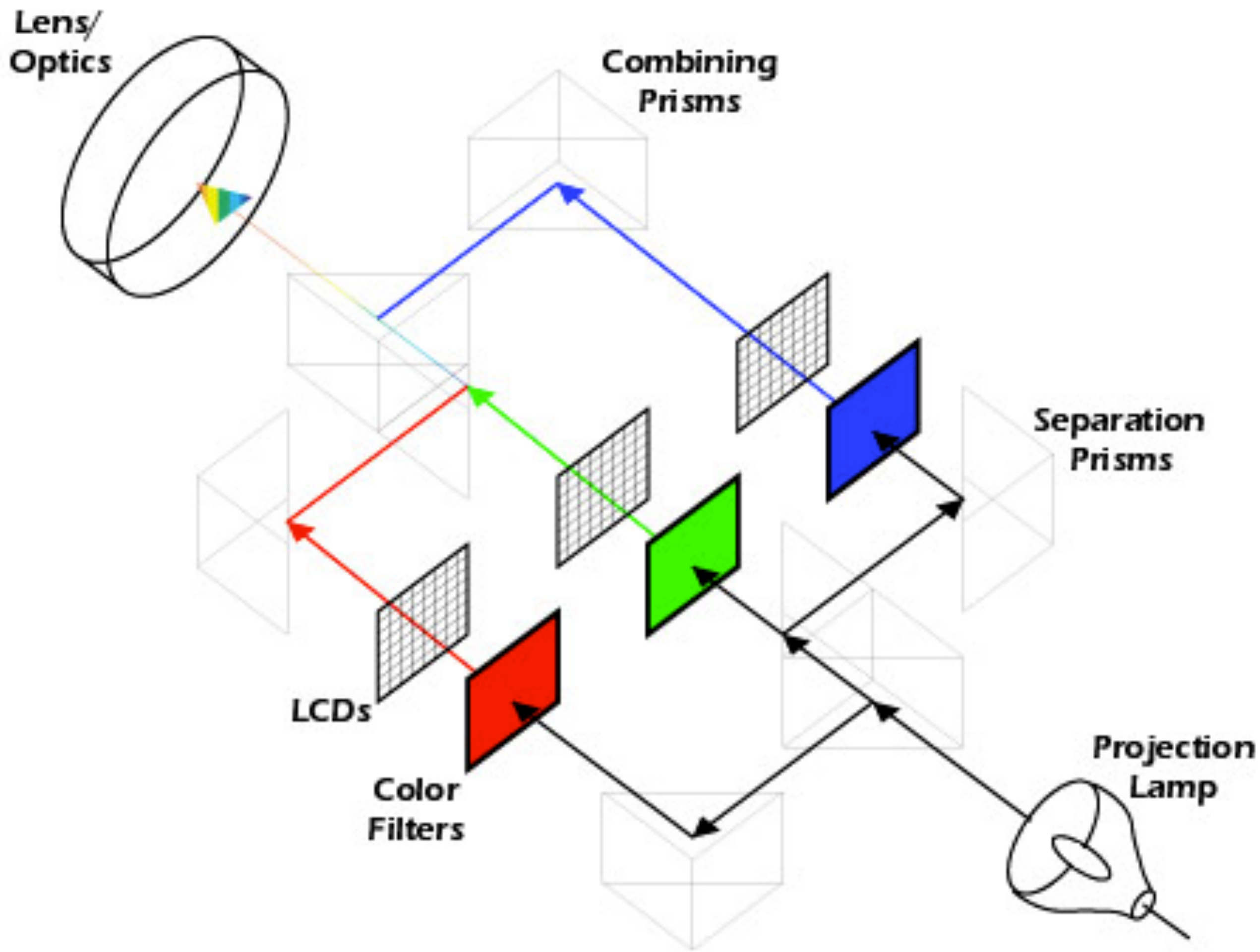
Dealing with distortion

- Flat display - rectangular image
- Curved display - distorts image
  - Needed on many large-scale displays
- Use CRT distortion to compensate
  - Use automatic hardware to control it
  - Complicates configuration
  - More frequent alignment problems

LCD projector



LCD projected systems

- Usually single projector
  - Brighter; Lower power; Less heat; Less noise
- BUT
  - Lower refresh rate
  - Low contrast (400:1 in typical projectors)
  - Produce polarized light: interferes with LCD shutter glasses
  - Harder to correct for curved screens

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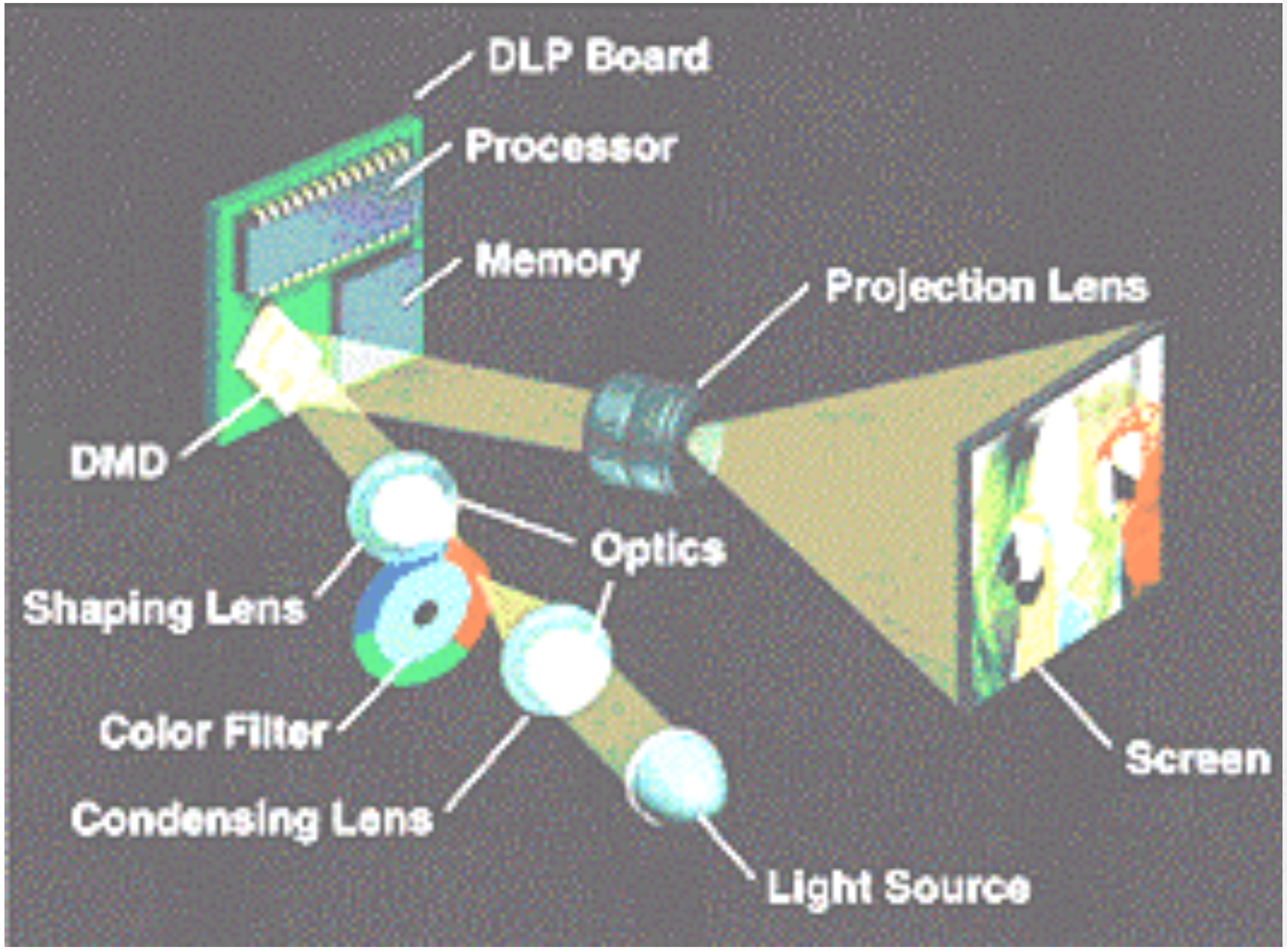
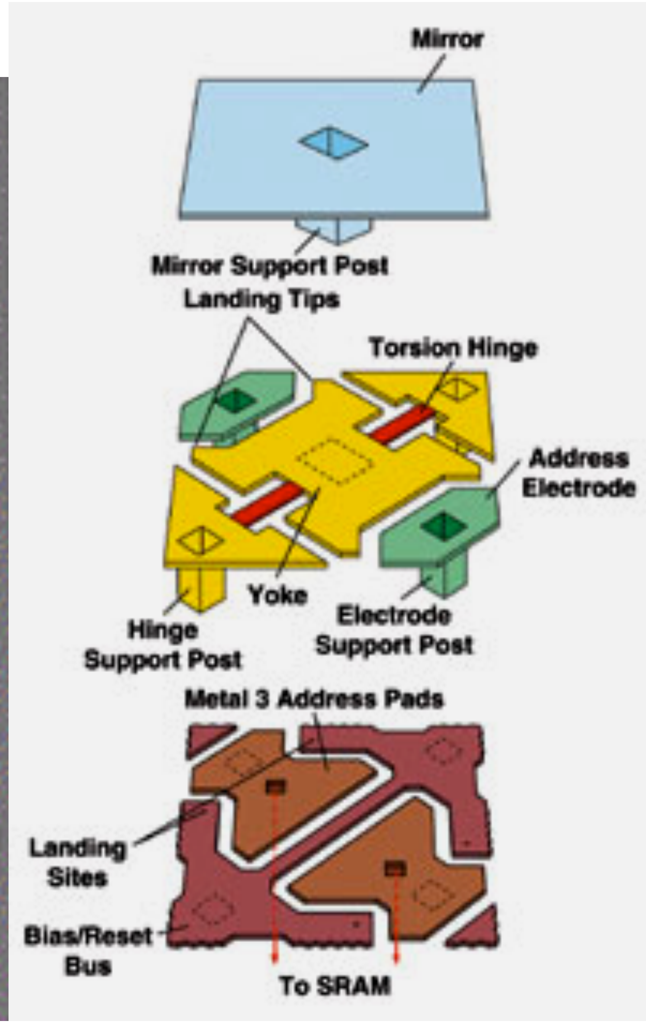
Digital projectors

- Digital Micro-Mirror Device (DMD)
  - Developed at T.I. Labs in 1994
  - Basis for digital cinema projection
  - 1.3 Million mirrors on a silicon chip
  - Each modulates reflected light, mapping pixel of video data to pixel on display
  - Digitally controlled: load data into memory cell located below the mirror.
  - Switching rate of thousands of Hz

DMD


DLP Board
Processor
Memory
Projection Lens
DMD
Optics
Shaping Lens
Color Filter
Condensing Lens
Screen
Light Source


Mirror
Mirror Support Post
Landing Tips
Torsion Hinge
Address Electrode
Yoke
Hinge Support Post
Electrode Support Post
Metal 3 Address Pads
Landing Sites
Bias/Reset Bus
To SRAM

Digital Light Processing (DLP)

- Electrostatical control of mirror tilt angle
  - +10 degrees (ON) or -10 degrees (OFF).
  - Light from ON mirrors passes through projection lens to screen.
- Digital Light Processing (DLP)
  - All digital display: completely digital except for A/D conversion at front end
  - Progressive display: displaying complete frames of video
  - Removes interlace artefacts such as flicker

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DLP cont

- “Square” pixels, fixed display resolution
  - Resolution fixed by number of mirrors on DMD
  - 1:1 aspect ratio of the pixels
- Requires re-sampling of various input video formats to fit onto DMD array
- Digital colour creation
  - Spectral characteristics of colour filters and lamp coupled to digital colour processing in the system

Quality

With LCD projector

With DLP projector

Stereo

- Depends on supplying separate image for each eye
  - Time-parallel (passive stereo)
  - Time-multiplexed (active stereo)

Active stereo

- One projector
  - Projects L/R images alternately
  - Quad-buffered stereo - special graphics cards required!
  - Typical refresh rate of projectors 120 Hz (60Hz for each eye)
  - Ghosting problems with CRT projectors (green phosphor too slow
  - Requires shutter glasses

Shutter glasses

- LCD display technology
  - Two crossed, polarized layers per eye
  - One permanently polarized
  - One switchable
  - Controlled by an IR signal

Pros and cons

- Expensive: > 100 GBP/pair
- Quite heavy - batteries and electronics inside
- Maintenance issues:
  - Batteries run out
  - Fragile
- Direct line-of-sight
- 50% light loss
  - could avoid with two active layers
- Single projector
  - Cheaper and easier to set up
  - But impact on frame rate

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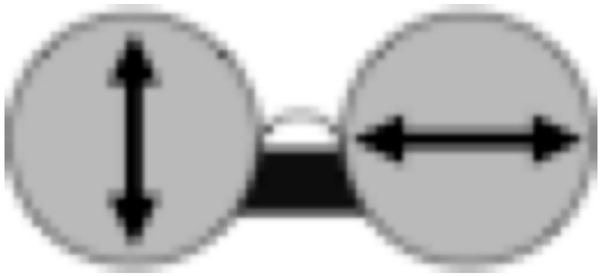
Passive stereo

- Two projectors
  - Polarize with each with different filter
- View with two lenses
  - Polarized in orthogonal directions



Pros and cons

- Cheap
- Light and comfortable
- More or less indestructible
- Continuous image in both eyes(2 projectors)
- Two projectors
  - Expensive
  - Alignment issues
  - Non-polarizing screen required
  - 50% light loss
  - Can't tilt head more than a few degrees

Stereo rendering

- Two camera ports
  - Slightly separated
- Can be calculated in software
  - But can be done in hardware on some graphics cards

Displays classification - 1

- Head-Mounted Displays (HMDs)
  - The display and a position tracker are attached to the user's head
- Head-Tracked Displays (HTDs)
  - Display is stationary, tracker tracks the user's head relative to the display.
  - Example: CAVE, Workbench, Stereo monitor

Differences

- HMD
  - Eyes are fixed distance and location from the display screen(s)
  - User line-of-perpendicular to display screen(s) OR at fixed, known angle to the display screen(s).
- HTD
  - Distance to display screen(s) varies
  - Line-of-sight to display screen(s) almost never perpendicular
  - Usually much wider FoV than HMD
  - May combine virtual and real imagery

Displays Classification - 2

- Non-immersive (desk-top) VR
- Semi-immersive VR
- Immersive Systems

Non-immersive VR

- workstation screen
- navigation using a mouse/spaceball
- stereo glasses

Semi-immersive VR

– Large screen
– stereo glasses
– datagloves
– position tracking

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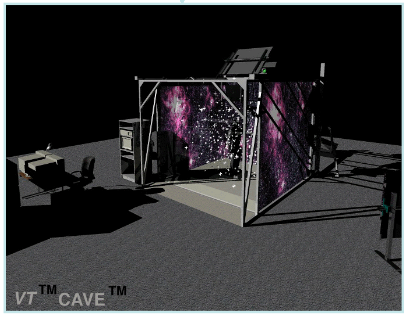
Immersive Systems

- Head Mounted Displays -HMD’s
- Cubical projection systems - CAVE
- datagloves, position tracking.



HMDs

- Still identified with VR in popular mind
- Originally CRT based: one screen/eye
  - High-end systems still are
  - Expensive, bulky, but higher resolution
- Less expensive systems are LCD-based
  - resolution: varies from 320x240 up to 1700x1350, standard 800x600
- Limited FoV
  - 25-100 degrees diagonal
  - See http://www.stereo3d.com/hmd.htm

Head Mounted Displays

Occulus Rift

- HMD for games partly financed by crowdfunding: $2.4m out of $91m
  - See http://en.wikipedia.org/wiki/Oculus_Rift
- Developer version: 1280x800= 640x800/eye; consumer ?1920×1080
  - Developer cost $300; consumer version ? summer 2014
  - LCD 7″ screen; 24 bit colour
  - Low latency tracker: 1000Hz
  - Adjustable eye distance; replaceable lenses
  - Inter-pupil adjustment in software

Resolution issues

- Number of pixels related to display area
- Pixel size also related to viewing distance
- Closer to a screen results in less resolution

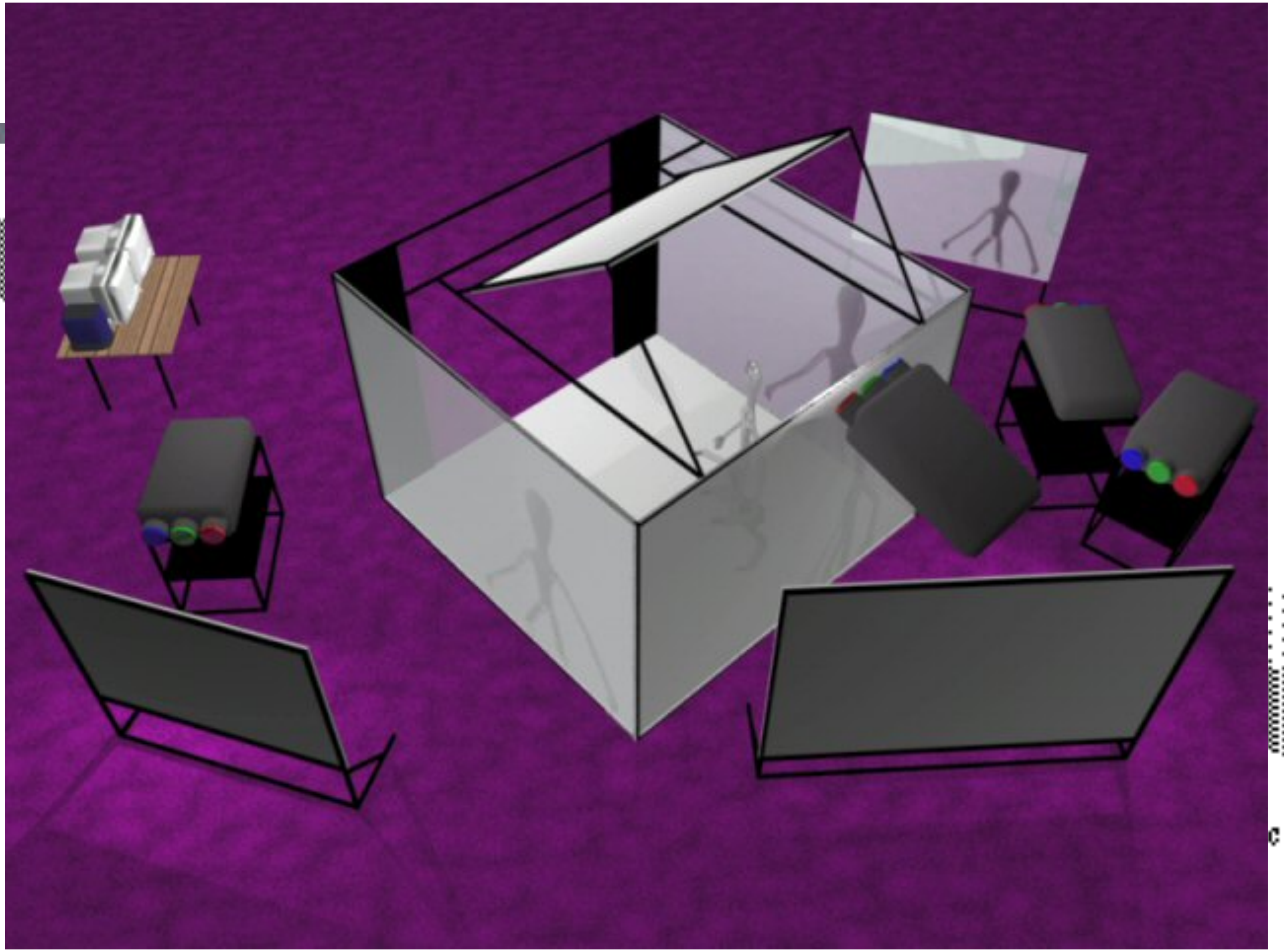
Accommodation v convergence

- All projected images actually at same distance
  - On the screen
  - Thus *constant* accommodation: unlike real world
- But manipulated to create convergence for eyes
  - Thus variable convergence
- Can create eye strain
  - HMDs have screens very close to the eye

Issues with HMDs

- Inter-pupil distance (IPD) needs to be adjusted
  - Or it puts extra strain on the eyes
- Resolution and FoV not very good
  - OcculusR remains to be seen
- Cannot see one's own body
  - Impairs presence
- Not collaborative
  - Becomes expensive in multiples especially at high end
- Cumbersome to wear
  - Especially over spectacles: need replacable lenses

CAVE



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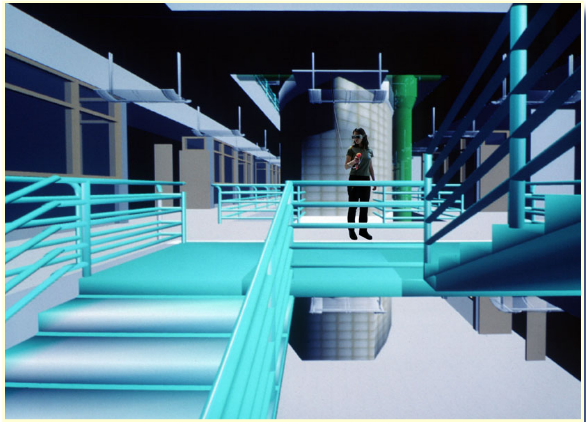
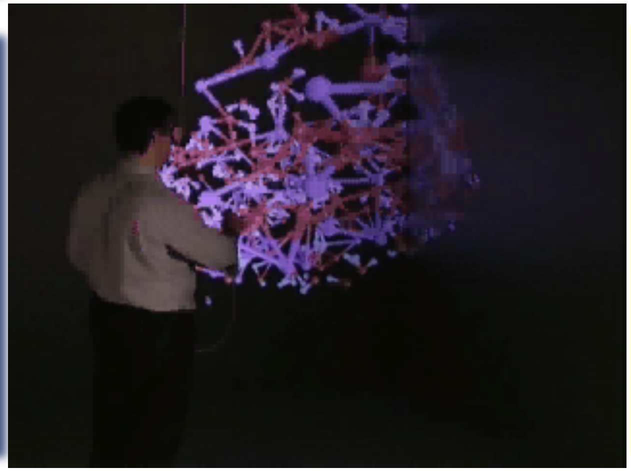
Characteristics

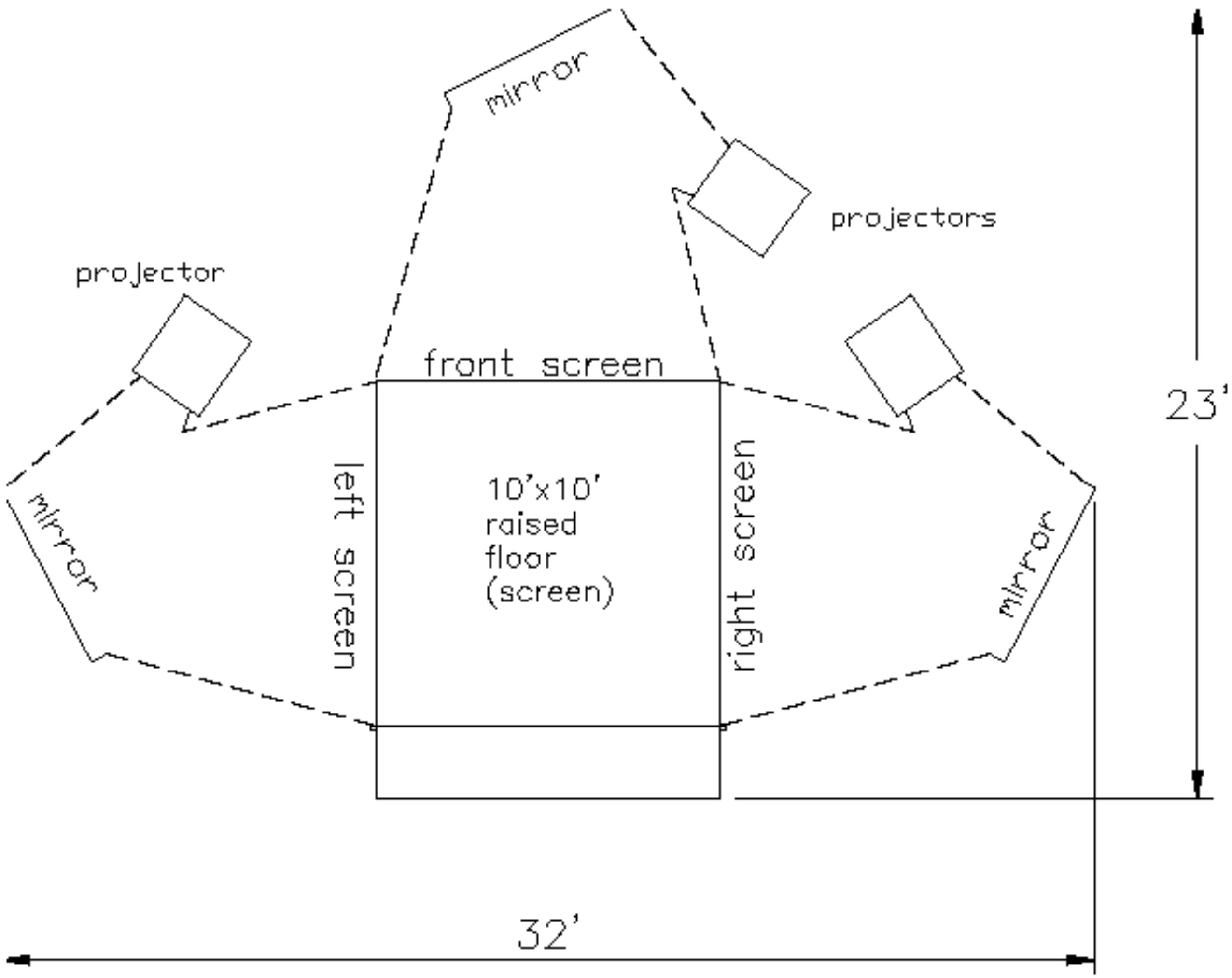
- 4-6 active stereo surfaces
  - Around 3m sq
  - Usually backprojected using mirrors
  - Floor sometimes front projected from ceiling
- Enclosure
  - Tracking system for ONE user
  - Can fit maybe 4 others into space
  - Often adds spatialised sound
- Can 'walk around' displayed objects
  - Can see own body - high presence
  - Occasionally people walk into a wall

Fully immersive




Large footprint!



Update rates

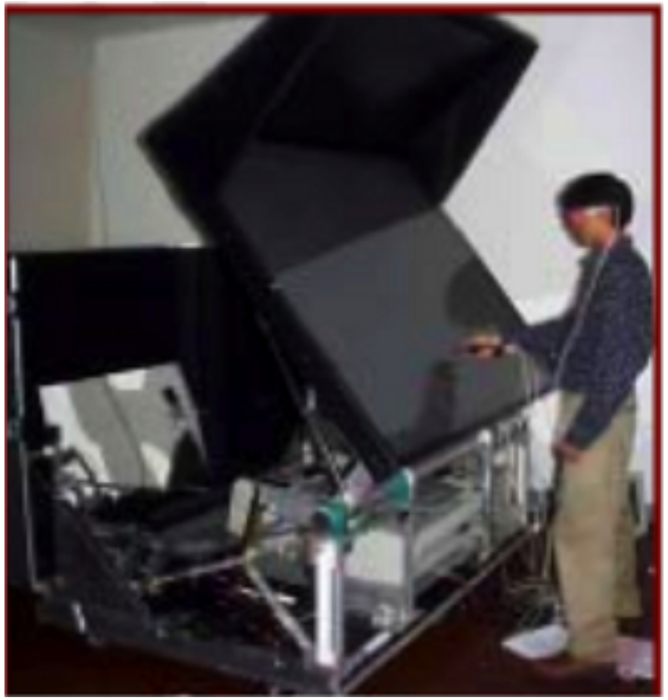
- Head turning not a problem
  - Unlike many HMDs
  - But much more computational power
- Fast head movement within space can be a problem
  - Tracking allows update
  - Sometimes with a bit of a lag

Computational requirement

- Originally large multi-graphic pipe rack system
  - One pipe per panel
  - SGI: contributed to high cost
- Current work
  - Use of PC cluster
  - x2 PCs per panel: one for each stereo channel
- Cluster issues
  - Software
  - Synchronisation
  - Large models

Workbench

- Immersadesk
  - Back-projected
  - Stereo
  - Objects float in front
  - Hand & head tracking
- Good for object interaction
  - Life-size (‘widgets’) or less-than-life-size (buildings in city models)
- Can link for collaboration



Semi-Immersive Display

- Reality Room
  - Three edge-blended front projectors
  - No tracking
  - 150 by 40 degree Horizontal and Vertical FoV
  - Engages peripheral vision

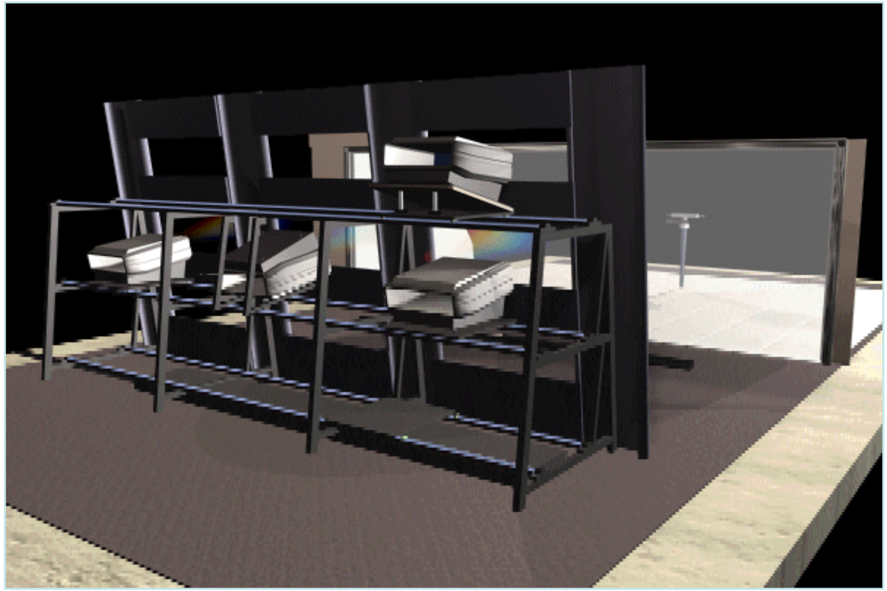
Characteristics

- Very good for spatial engagement
  - Very large FoV
  - Building interiors
  - City models
- Good for collaborative work
  - 20 people
  - Design reviews
  - Popular in oil industry
  - Public involvement in urban planning decisions

Issues

- Interactively weak
  - Driven by one person with a mouse (possibly 6 dof): no head tracking
  - Can produce cybersickness especially for fast movement
- Projector 'blending' can be a problem
  - Often visible
  - Projectors need frequent tuning to hide it
- Must compensate for curved screen
  - Usually best done with CRT displays: less bright

WorkWall



Features:

- flat screen
- two or more edge blended projectors
- rear projected

WorkWall

- Screen size: (two configurations)
  - 8.0' h x 16.0' w and 8.0' h x 24.0' w screens (2.1m h x 4.9m w and 2.4m h x 7.3m w)
- Size: Scaleable display setup is.
- Work Group Size: Ideal for two to forty viewers
- Maximum Resolution:
  3 Projector System 3456 x 1024 resolution
  2 Projector System 2304 x 1024 resolution

Dome/sphere displays

- Multiple projector system
  - Project onto domed surface above
  - 180 deg or more
    - e.g Trimension V-dome: Hayden planetariium, American Museum of Natural History
    - 180x180; 21 m diameter; 7 projectors
- ETH Zurich Visdome

Solving the movement problem

- Cybersphere
  - Bearings at base
  - Rotates as walk

Factors in choosing displays

- Degree of immersiveness and presence needed
  – Relationship to virtual space
  – Objects life-size or not?
- Amount of interactivity needed
  – Balance between object interactivity and navigation
- Degree of cooperative working
- Space requirements and cost

Technologies under development

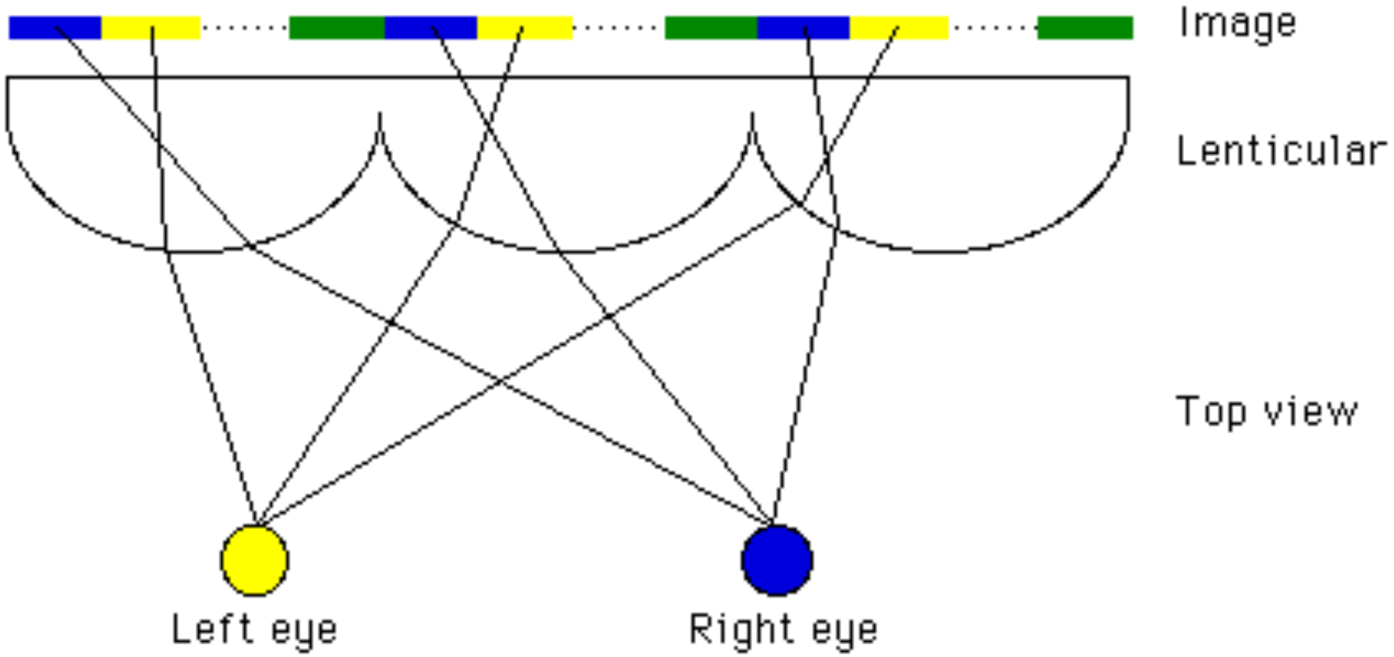
- Auto-stereoscopic
  - Commercially available but non-interactive
- Virtual Retinal display
  - Still being researched

Auto-stereoscopic

- Stereo without glasses
  - Both halves of stereo pair displayed simultaneously, directed to corresponding eyes
  - Uses special illumination plate behind the LCD: light from compact, intense light sources
  - Optically generates lattice of very thin, very bright, uniformly spaced vertical light lines
  - Lines are spaces with respect to pixel columns of the LCD
  - Left/right eye sees lines through odd/even columns

Lenticules

- Lenticular sheet
  - contains series of cylindrical lenses molded in plastic substrate.
  - lens focuses on image behind lenticular sheet.
  - Each eye's line of sight focused onto different strips.



Current state

- Laptop with auto-stereo screen available
- Non-interactive display for product display
  - Similar to plasma screen size
- Sensitive to head position
  - Too slow for interaction right now

Virtual Retinal Display (VRD)

- Scan light directly onto retina
  - No screen needed
- Idea from scanning laser ophthalmoscope
  - Used to acquire picture of retina
- Work at University of Washington

  http://www.hitl.washington.edu/research/vrd/

Laser-based

- VGA video source (640x480)
- Argon for blue and green
- Laser diode for red
- Control and drive circuits
  - Direct modulation of laser diode
  - Indirect modulation of argon source

VRD

- Scanned onto retina using
  - Horizontal: mechanical resonant scanner
  - Vertical: galvanometer
- 40 nsec on retina with no persistence
- Scan loops instead of flyback
  - 60 Hz interlaced
  - Final scanned beams exit through lens
- User puts eye at exit pupil of VRD to see image
  - Total: 307,200 spots of non-persistent lights

Characteristics

- Perceived without flicker
  - With vibrant colour
- Seen both in occluded and augmented viewing modes
- Extremely small exit pupil
  - Large depth of focus

Advantages

- Large colour range
- Theoretical resolution limits set by eye
- Luminance should be safe
  - 60-300 nW for perceived equivalent brightness
  - 3-4 times less power than CRT
- Better contrast ratio than CRT
- Better depth of focus
  - Like a pinhole camera
- Low power consumption (if using laser diodes)
- Theoretically very cheap

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Issues

- Problem with head movement
  - Lose the image
- Needs an argon laser
  - Large and costly
  - But red, green, and blue laser diodes are coming
- Safety issues still not clear
  - Coherent light vs. non-coherent
- Need better resolution and larger FoV
- Want portable version (eye glasses)

FogScreen Inia

- Frameless walk-through screen by Inition
- Fog screen injected into a laminar airflow
  - Translucent / fully opaque images projection
  - 2 metres wide X 1.5 metres high
- Fog – ordinary water & ultrasonic waves

FogScreen Inia

- Standard video projectors
  - 2 projectors: different images on both sides of the screen
  - At least 3000 ANSI Lumens
  - Can use both back & front projection
  - Min 2 metres between projectors and screen
  - Better result with a darker background
- 25.6" (65cm) high x 35.4" (90cm) deep x 91" (2.31m) wide, Weight 150kg.
- Interactivity through pointer stick

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Conclusions

- Display technology still imperfect
  - New technologies being developed
  - Still problems with resolution, brightness, FoV
- A number of different display systems
  - Different characteristics
  - Choose in relation to application