Displays: Optics and Devices

IAT351

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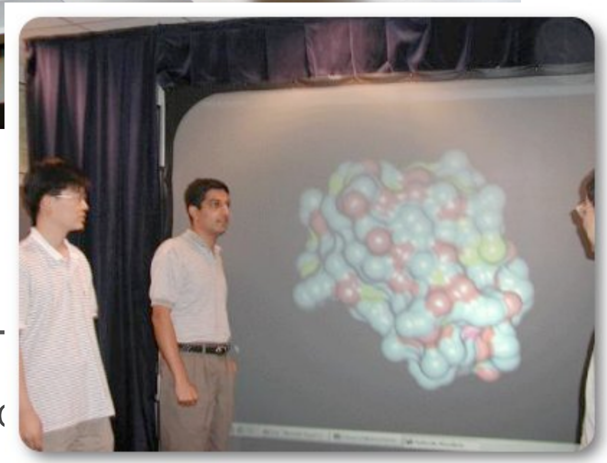
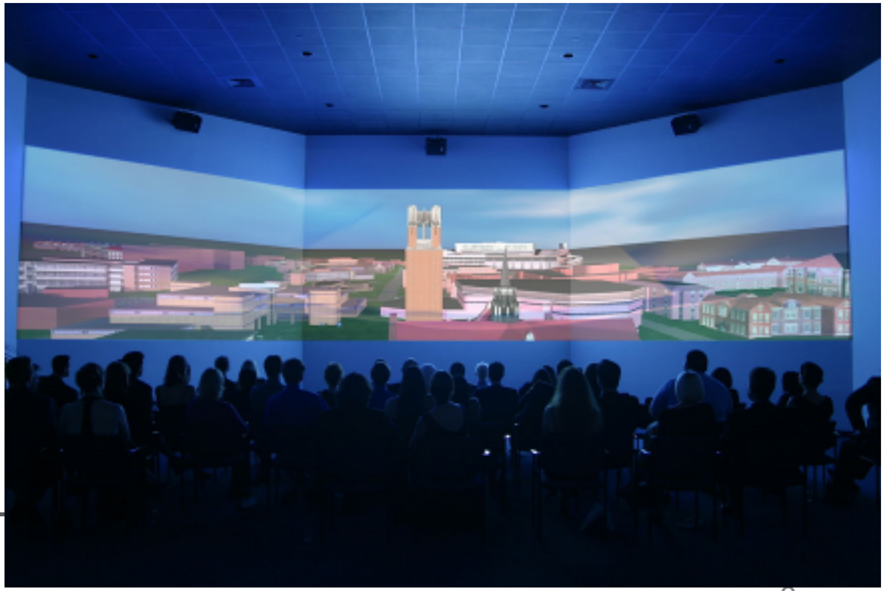
Displays – Small and Large

Primary source of **feedback**

- Physical dimensions (usually the diagonal dimension and depth), weight
- Resolution (the number of pixels available)
- Number of available colors, color correctness
- Luminance, contrast, and glare
- Power consumption
- Refresh rates (sufficient to allow animation and video)
- Cost
- Reliability





Displays – Contexts of use

Usage characteristics distinguish displays:

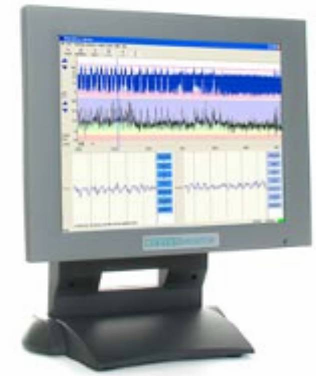
- **Portability**
- **Privacy**
- **Saliency**
- **Ubiquity**
- **Simultaneity**
- **# users**
- **Capacity of users**

Contexts of use set constraints:

- **Direct/desktop/**
- **Ambient**
- **Peripheral**
- **Focused/transient**
- **Private/public**

Display Technology

- Monochrome displays (single color)
  - Low cost
  - Greater intensity range (medical)
- Color
  - Raster Scan CRT
  - LCD – thin, bright
  - Plasma – very bright, thin
  - LED – large public displays
  - Electronic Ink – new product w/ tiny capsules of negative black particles and positive white
  - Braille – refreshable cells with dots that rise up



Large Displays

- Wall displays
  - Informational
    - Control rooms, military, flight control rooms, emergency response
    - Provides
      - System overview
      - Increases situational awareness
      - Effective team review
  - Interactive
    - Require new interaction methods (freehand sketch, PDAs)
    - Local and remote collaboration
    - Art, engineering

Large Displays

- Multiple Desktop Displays
  - Multiple monitors for large desktops
  - Cheap
  - Familiar
  - Spatial divide up tasks
  - Comparison tasks are easier
  - Too much info?
- Problems?
- Eventually -> Every surface a pixel

Mobile device displays

- Personal
  - Reprogrammable picture frames
    - Digital family portrait (GaTech)
- Medical
  - Monitor patients
- **Research:** Modality Translation Services (Trace Center – University of Wisconsin)
  - As you move about it auto converts data, info, etc. for you

Displays – Large and Small (cont.)

- Heads-up and helmet mounted displays
  - A heads-up display can, for instance, project information on a partially silvered widescreen of an airplane or car
  - A helmet/head mounted display (HMD) moves the image with the user
  - 3D images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Google Glasses™

Why should we care about optics?

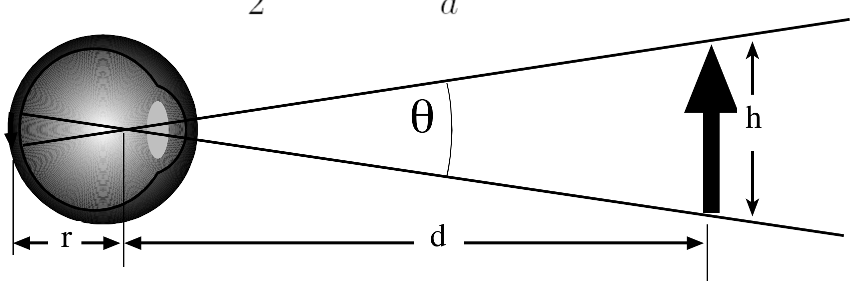
- Hi bandwidth to the brain (70% of all receptors ,40+% of cortex, 4 billion neurons)
- Can see much more than we can mentally image
- Can perceive patterns
- *Ma*tch of *display resolution* and *visual acuity*

- Display resolution
  - design according to the available display resources
- Visual Acuity
  - Limitations of the human visual system

Visual angle

- Size and and viewing distance affect the *visual angle subtended* by the viewed object
- Visibility is affected by visual angle
  - 1 arcmin = 1/60 degree of visual angle
  - the angle under which a visual stimulus appears to the eye

$$\frac{\theta}{2} = \arctan\left(\frac{ab}{d}\right)$$



Visual angle and FOV (field of view)

- Normal vision
  - Distinguish an object that subtends 1/60° at a distance of 20 ft
  - FOV = 150° per eye

- A thumbnail at arm's length = 1 degree of visual angle
- 1 cm object at 57 cm = 1 degree of visual angle
- 57 cm is a reasonable approximation of usual monitor viewing distance

Resolution

- Number of pixels
- Sharpness depends on resolution and size
  - Small pixels are sharper than fat oneso
- *Display resolution* = size x resolution

- Low display resolution limits information
  - BUT adding pixels won't help!
- Object must subtend a minimum angle

Display size cont.

Large displays afford greater FOV

- Limitation on what humans can process in horizontal and vertical FOV
  - Peripheral vision is highly unacute for many visual features
- People perform better on certain spatial orientation tasks using large displays
- Wider FOV increases presence
- To a certain extent, can have higher resolution
- Large displays are not portable!

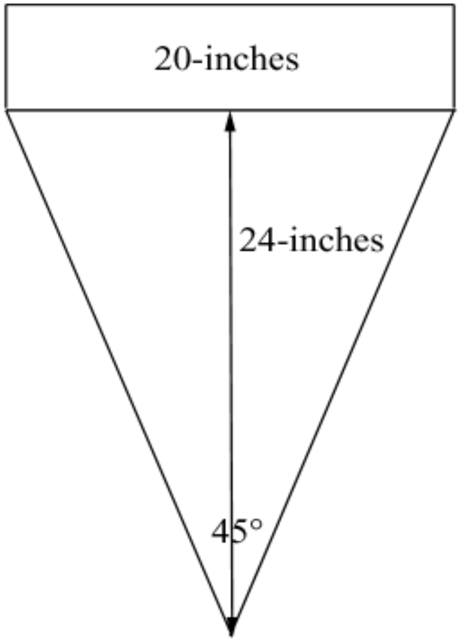
Human optics

- The brain and eye have orders of magnitude more receptors than displays have pixels (stimuli)
- A screen may have 30 pixels/cm – need about 4 times as much.
- VR displays have 5 pixels/cm

- Fovea in the centre of the eye has the most acute vision
- *Visual acuity*: Measurement of our ability to see detail

Resolution of Eye

- Resolution of the eye ranges from 0.5 *arc minute* to 1 arc minute



How many pixels across one scanline subtending 45° would it take to match human visual acuity?

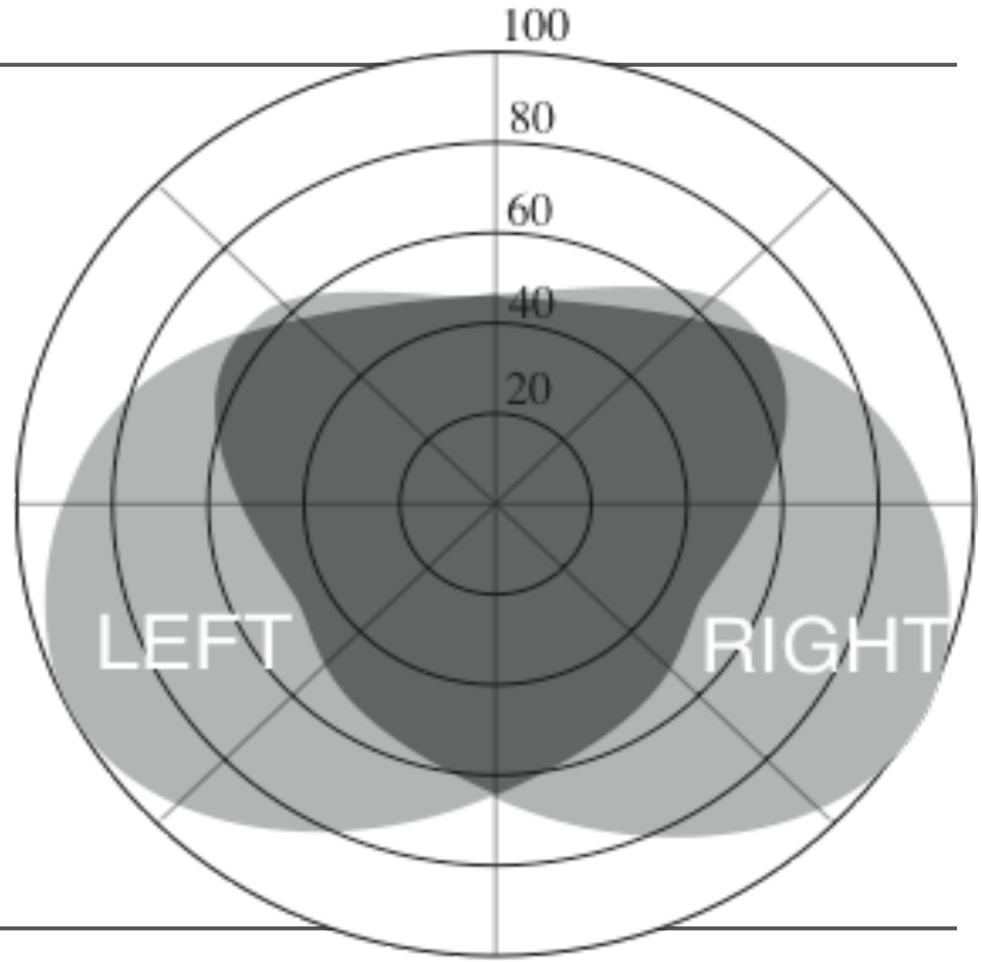
Answer: 120x45 = 5400 pixels

But …

That's in the **fovea**

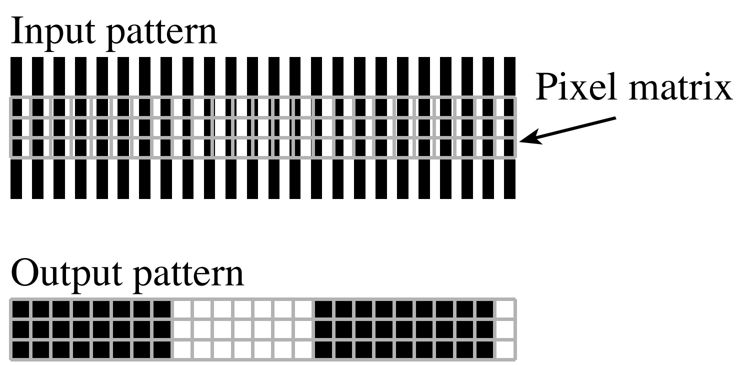
Human Visual Field

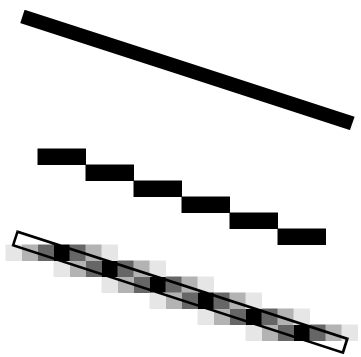
- Area of overlap is approximately 120° with 30-35° monocular vision on each side
- Combined horizontal FOV is 180-190°
- Combined vertical FOV is 120-135°



Overcoming device resolution

- we can use the ability of the eye to integrate information over space and time to support perception of higher-than-device resolution
- Anti-aliasing
  - Spatial
  - temporal





Fundamental questions

- How many pixels are needed to represent information effectively?
  - Resolution
  - depth
- What's the size and brightness (visual acuity) needed for our visual system to accurately identify and interpret the visual features?

[1] Awant and Healey, A survey of display device properties and visual acuity for visualization

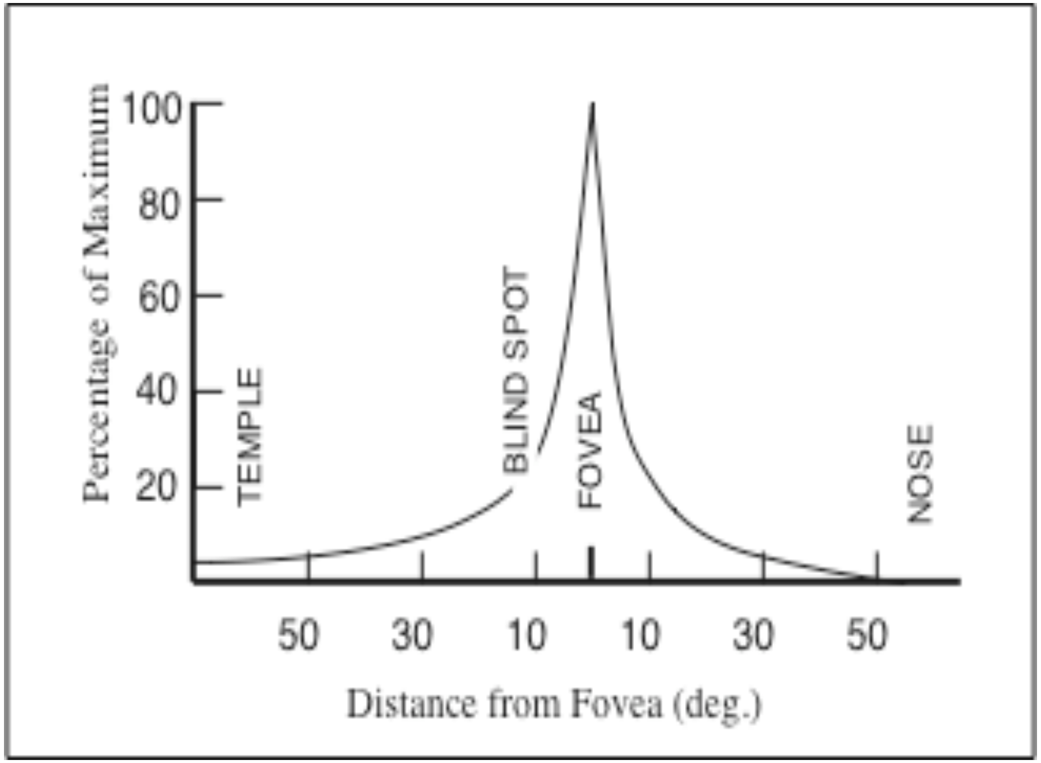
Visual Acuity Properties

Device	Resolution	Screen Size	Distance	Angle
Phone	128 x 160	2-inches	18-inches	1,52-arc min
PDA	240 x 320 600 x 800	3.5-inches 4-inches	18-inches	1,40-arc min 0,46-arc min
Monitors	1024 x 768 1280 x 1200 1600 x 1200	17-inches 17-inches 17-inches	24-inches	1,54-arc min 1,31-arc min 1,13-arc min
Powerwall	3200 x 2400	8 x 6-feet	4-feet	2,09-arc min
Electronic ink	2550 x 3300	8.5 x 11-inches	18-inches	0,38-arc min

Size (and angle) matters

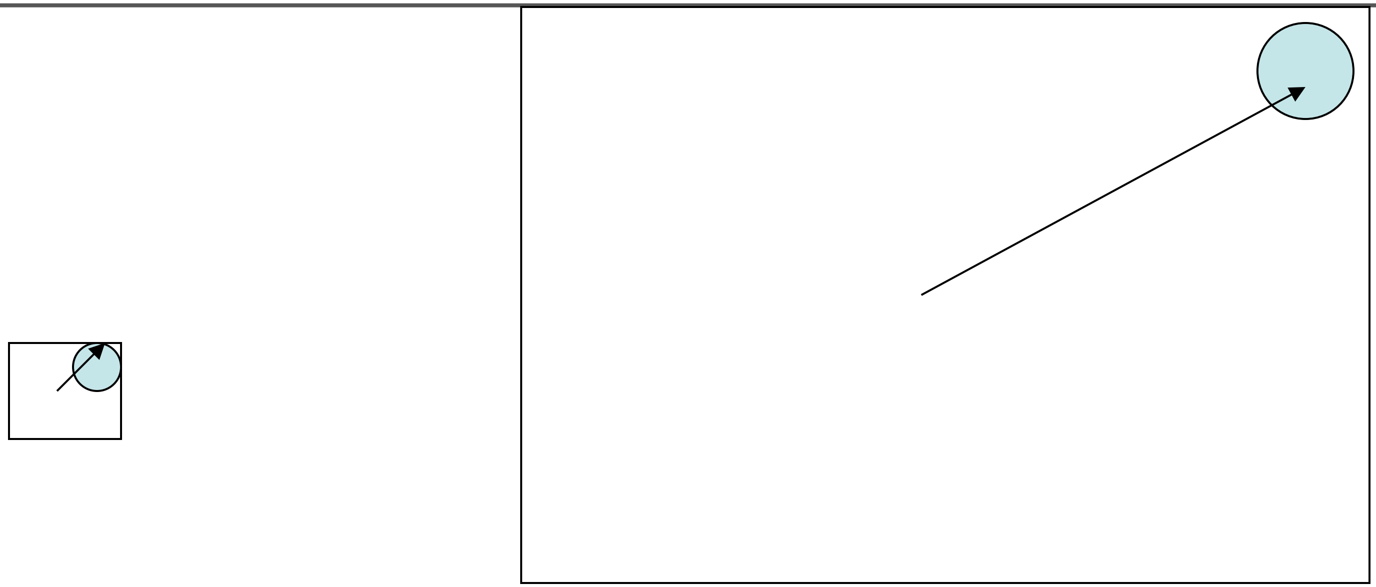
- Visual acuity is NOT uniform across the FOV
- Fovea subtends a small region (2 degrees)
  - Parafovea covers about 6-8 degrees
  - So we only resolve something clearly if we look right at it
- Limits effective resolution of display
- Increases the time we need to “see” it
- Some visual features are non discriminable in the periphery

Acuity Distribution



An image progressively blurred from the centre outwards simulating the progressive loss of acuity with eccentricity.

How efficiently can we use each display?



It will take approximately 2.5x as long to fixate targets at the edge of the big screen

Head movements accompany eye movements > 25 deg.

How Many Pixels? Visual features

- Each visual feature needs some minimum number of pixels
  - Hue, luminance, flicker need 1 pixel
  - Orientation, size, regularity need more pixels

- Minimum number of pixels for certain features is unknown
- Importance
  - Help to validate a data-feature mapping
  - Characterize to what extent we saturate "visual bandwidth"

- Effectiveness of a display type will depend on what you want to show
  - Key visual features (detail? Text? Luminance? Colour?)

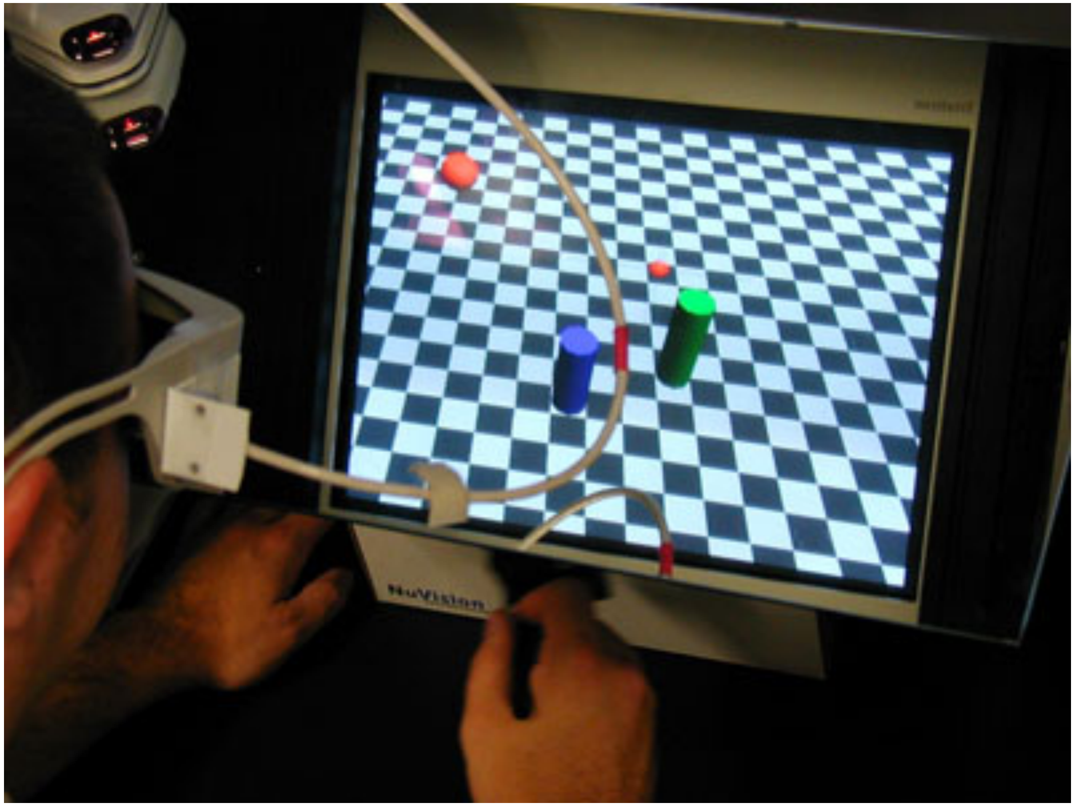
Visual features

- Colour, size, position, luminance, shape, flicker, motion
- Colour (hue) visibility depends on saturation and size
  - ½ degree of visual angle
- Humans are almost colour-blind in the periphery
- Subject to interference (dithering)
- “never the same colour”

Visual features cont.

- Luminance
  - Intensity or brightness of the colour
  - Evidence shows we see luminance before colour
  - We are more sensitive to luminance changes outside fovea than other static cues
- Generally, static cues like position and shape are also marginally perceptible in the periphery
- Motion a powerful visual cue across the FOV
- we need to fixate (foveate) most visual information to decode it
- What does that say about choosing/building displays?

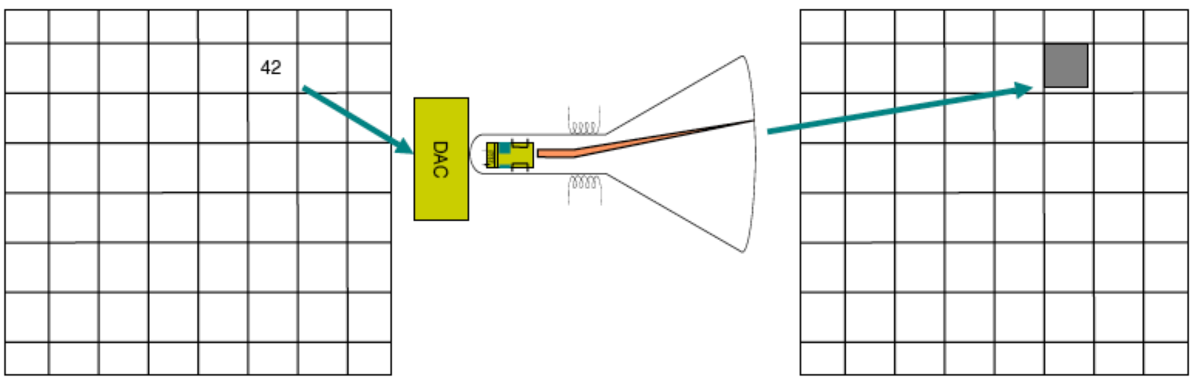
Ultimate Display



How they work: Frame buffer

- Pixels are determined by 2D array of intensity values in memory
- Each memory cell controls 1 pixel

Frame buffer



- All drawing done by placing values in memory – must be there before *refresh*

- Eye’s perception (as we have seen) is not linear
- Different displays have different dynamic ranges
  - Different colours different devices!
  - Need to compensate

- Display tests
- Put these on your laptop monitors and see if they are the same as each others’ and the projector
- LCD colour tests

Developments in Displays

The major players:

- CRTs (they' re still around)
- LCDs
- Plasma (PDP)
- Projectors
- LEDs

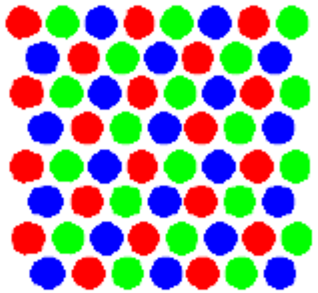
Some of the newer entries:

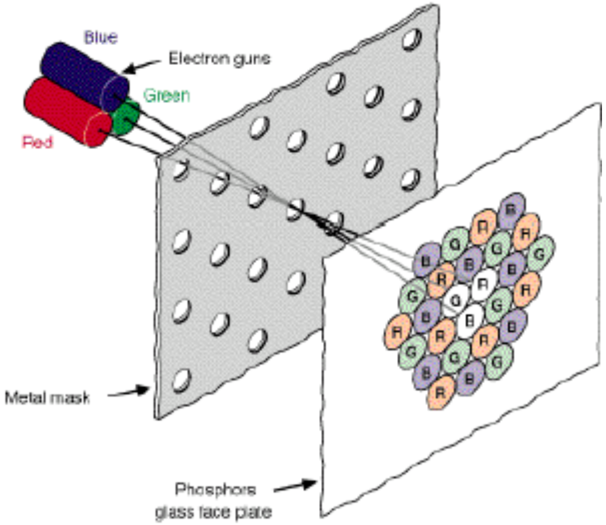
- OLEDs
- FEDs
- Flexible displays; electronic books
- 3D (if we have time and patience)

Main technologies: CRT

- Analog
- 3 electron guns (R,G,B) excite phosphors on screen
- True colour
- Heavy
- Big
- Still best image quaity

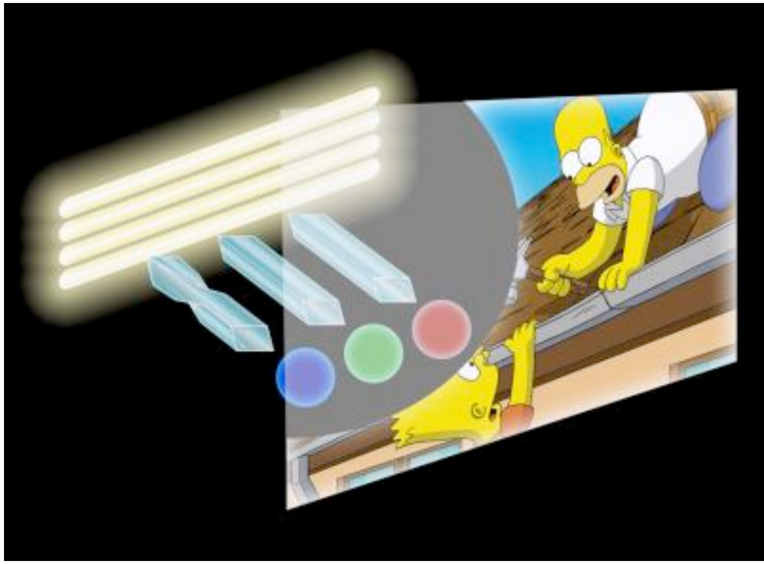
Delta Electron Gun Arrangement





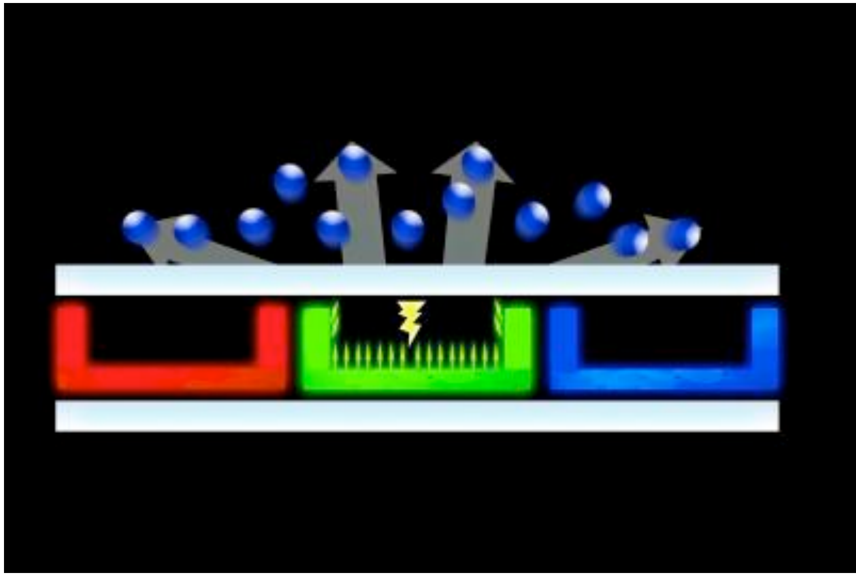
Main technologies: LCD

- Basic idea: backlight shines through layer of liquid crystals that twist to let light through colour filters
- Adjusting the voltage applied controls how much the crystal untwists, permitting variable light pass-through
  - = gray levels! 256
- Delivers true colour (24 bit)
- lots of transistors - 2,359,296 for 1024x768
- Power efficient



Main technologies: Plasmas

- Basic idea: a matrix of tiny fluorescent lights
- Excite the gas (plasma) in the tubes to emit light
- phosphors emit light uniformly
- Heavy
- BIG power consumption
- True black (absence of light)
- Some burn-in

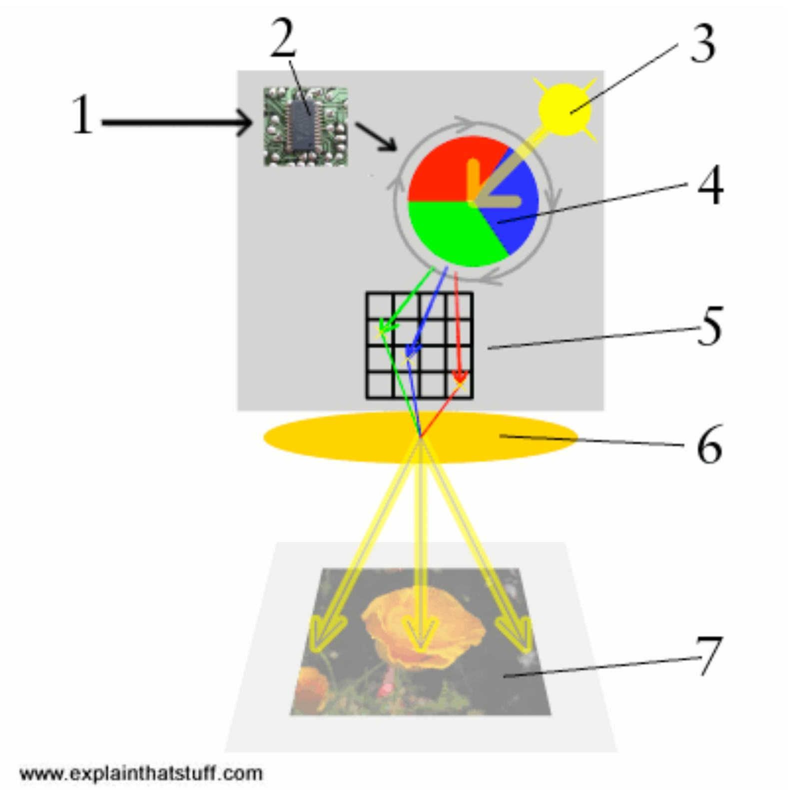


Main technologies: projection

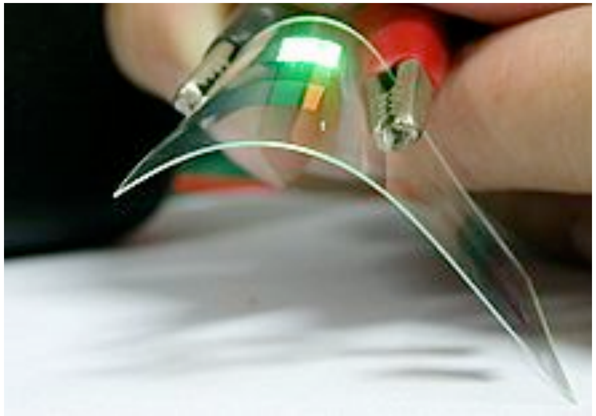
- Light is passed through a series of colour screens or plates and cast on a flat surface
- LCD, LED, CRT and DLP
- Dependent on:
  - LIGHT OUTPUT: 1500 – 4000 lumens for monitor-sized screen
    - Enormously more for large, cinema screens
  - Throw distance/angle
- Usually fixed installation
- New small LED units are portable

How DLP works

1. Digital in signal.
2. decoding.
3. Whilte light from lamp.
4. A rapidly rotating colored wheel generates either red, blue, or green light at any particular instant.
5. Light reflects off two million K mirrors in a tiny DMD chipthat rapidly swivelled so they generate a precise pattern of red, blue, and green pixels to make up the TV picture.
6. A lens collects and focuses the light
7. The screen displays magnified image.



OLED (Organic light emitting diode)



- Emits light without backlight
- Deep blacks, high contrast ratio
- Lower light than LED
  - Poor readability in bright ambient light
- White increases power use
- Relatively poor blues
- Can be used with polymers and other flexible compounds
- Shorter lifespan
- Mobile phones, digital cameras

3D and Virtual reality

- enables users to interact with objects and navigate in 3D space
- Immersive or augmented
- Glasses, heads up display or fixed position monitors
- VR has very poor resolution
- Stereo viewing problematic
- Head mounted displays follow head movement in virtual space
- Can cause motion sickness and disorientation

(some) Issues to consider ?

LCD

- No geometric distortion
- Light
- Some screen flicker from dimming
- Very bright
- No true black
- Poor peripheral view
- Power-efficient
- No burn-in
- 1 native resolution

Plasma (PDP)

- Rich colours
- True black
- Excellent viewing angles
- Fast
- Large pixel pitch (large screen)
- Heavy
- Some burn-in
- Sensitive to high altitude

(some) Issues to consider ?

CRT

- multiresolution
- Best image quality (?)
- Very high contrast ratio
- fast
- Excellent viewing angles
- large
- flicker
- heavy
- big
- Burn-in

Projection

- Scales up
- Light sources are expensive, have limited life
- New optical designs can produce very compact projectors
- Problems with ambient light
- Engines expensive