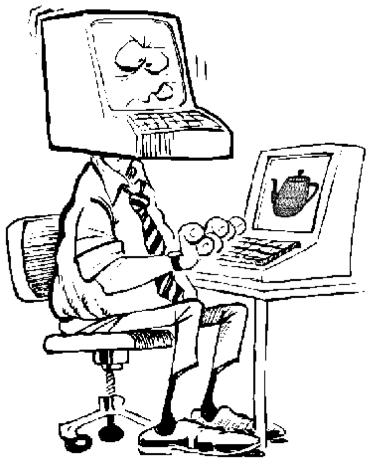
6.837/6.838 - Principles of Computer Graphics



Introductions

Instructors - Leonard & Julie
TAs - Hector, Jason, & Mok
Secretary - Bryt

About this Course

www.graphics.lcs.mit.edu/classes/6.837/F00

Computer Graphics?

Display Technologies

Computer Graphics

What computers do....

process, transform, and ***communicate*** information

Aspects of communication

- Origin (where does information come from?)
- Throughput (how frequent?)
- Latency (how long do I have to wait)?
- Presentation (what does it look like?)

Computer Graphics is...

the technology for presenting information

Okay, but... what is this course really about?

Not!

Paint and Imaging packages (Adobe Photoshop)
CAD packages (AutoCAD)
Rendering packages (Lightscape)
Modeling packages (3D Studio MAX)
Animation packages (Digimation)
Graphics APIs (OpenGL)
Graphics Modeling and Languages (RenderMan)

We will cover...

Graphics programming algorithms
Graphics data structures
Color and human vision
Graphical interface design and programming
Applied geometry and modeling
Applied numerical computing

Ugh... sounds like Computer Science

Computer Graphics is about **Movies**!

If you can imagine it, it can be done with computer graphics.

Obviously, Hollywood has caught on to this. Each summer, we are amazed by state-of-the-art special effects. More and more of these images exist only within the memory of a computer. There seems to be no end in sight for this trend. But we're not just talking about big budget mega-productions. There are music videos, and spinning logos on the 6 o'clock news. Computer graphics is now as much a part of the entertainment industry as stunt men and makeup.

The entertainment industry plays many other important roles in the field of computer graphics.

1. Leaders in quality and artistry
2. Not slaves to conceptual purity
3. Big budgets and tight schedules
4. Constant reminder that there is more to CG than technology.
5. How did they do that?
6. They define our expectations.

Games are okay here!

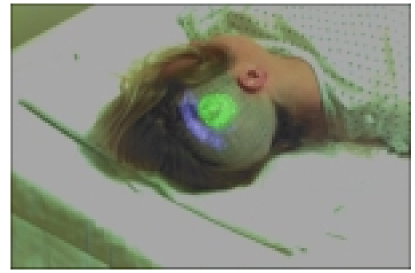
Games are an important driving force in computer graphics. In this class we are going to talk about games. We'll discuss on how they work. We'll also question how they get so much done with so little to work with. If you have time to play computer games between now and the end of the semester ask yourselves, how do they do that? Study the screen. How does the screen look when things are moving? What about when things are still. Why do they always go into those low resolution display modes that everyone else considers worthless. Let yourself get blown up. If anyone asks, tell them you're doing science.

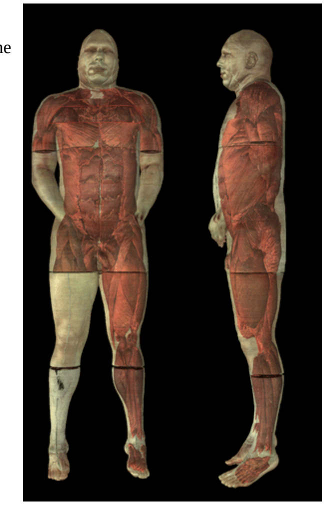
How the game's industry impacts computer graphics

1. Focus on interactivity
2. Cost-effective solutions
3. Avoiding computation and other tricks
4. Games drive the baseline

Medical Imaging

There are few endeavors more noble than the preservation of life. Today, it can honestly be said that computer graphics plays an significant role in saving lives. The range of application spans from tools for teaching and diagnosis, all the way to treatment. Computer graphics is *tool* in medical applications rather than an a mere artifact. No cheating or tricks allowed.

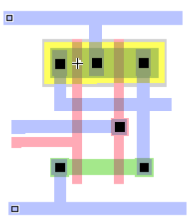




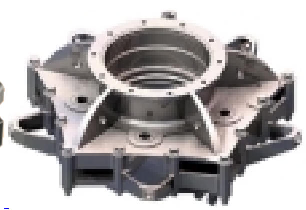
How medical applications influence computer graphics technology

1. New data representations and modalities
2. Drive issues of precision and correctness
3. Focus on presentation and interpretation of data
4. Construction of models from acquired data

Computer Aided Design



Computer graphics has had a dramatic impact on the design process. Today, most mechanical and electronic designs are executed entirely on computer. Increasingly, architectural and product designs are also migrating to the computer. Automated tools are also available that verify tolerances and design constraints directly from CAD designs. CAD designs also play a key role in a wide range of processes from the design of tooling fixtures to manufacturing.

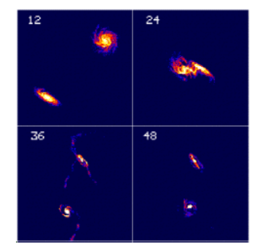


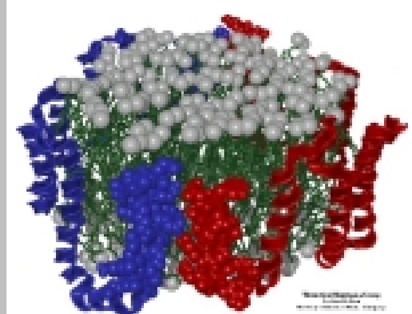
CAD has had the follow impact on computer graphics.

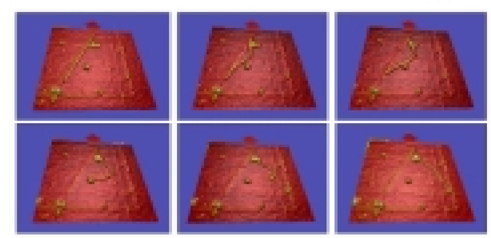
1. Drives the high-end of the HW market
2. Integration of computing and display resources
3. Reduced design cycles (faster systems sooner)

Scientific Visualization

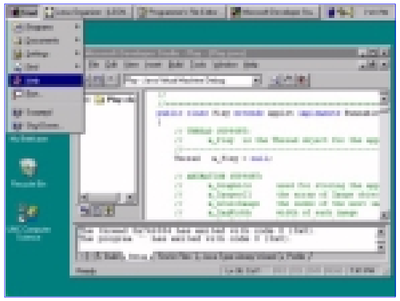
Computer graphics makes vast quantities of data accessible. Numerical simulations frequently produce millions of data values. Similarly, satellite-based sensors amass data at rates beyond our abilities to interpret them by any other means than visually. Mathematicians use computer graphics to explore abstract and high-dimensional functions and spaces. Physicists can use computer graphics to transcend the limits of scale. With it they can explore both microscopic and macroscopic worlds.



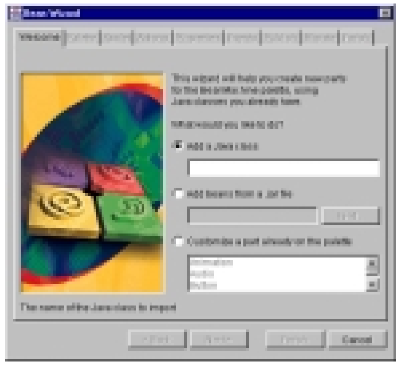


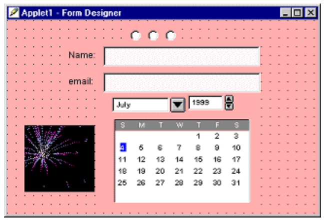


Graphical User Interfaces (GUIs)

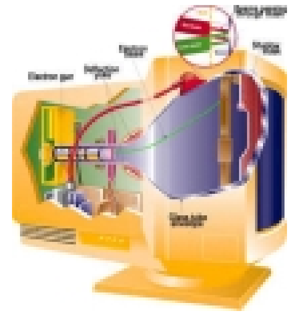


Computer graphics is an integral part of every day computing. Nowhere is this fact more evident than the modern computer interface design. Graphical elements such as windows, cursors, menus, and icons are so common place it is difficult to imagine computing without them. Once graphics programming was considered a speciality. Today, nearly all professional programmers must have an understanding of graphics in order to accept input and present output to users.





Display Technologies



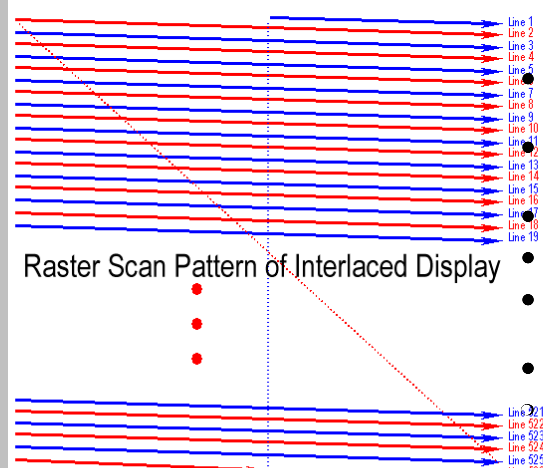
Cathode Ray Tubes (CRTs)

- Most common display device today
- Evacuated glass bottle
  (last remaining vacuum tube)
- Heating element (filament)
- Electrons attracted to focusing anode cylinder
- Vertical and Horizontal deflection plates
- Beam strikes phosphor coating on front of tube

Vector Displays

- Oscilloscopes were some of the 1st computer displays
- Used by both analog and digital computers
- Computation results used to drive the vertical and horizontal axis (X-Y)
- Intensity could also be controlled (Z-axis)
- Used mostly for line drawings
- Called *vector*, *calligraphic* or affectionately *stroker* displays
- Display list had to be constantly updated
  (except for storage tubes)

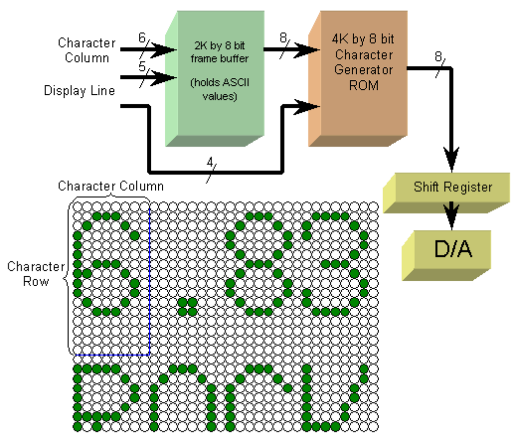
Raster Displays



- TV boomed in the 50s and early 60s
  (they got cheap)
- B/W TVs are basically oscilloscopes
  (with a hardwired scan pattern)
- Entire screen painted 30 times/sec
- Screen is traversed 60 times/sec
- Even/Odd lines on alternate scans
  (called fields)
- Interlace - a *hack* to give
  - Smooth motion
    on dynamic scenes
  - High Resolution
    on static scenes
  - Optimize bandwidth

Raster Display Simulation

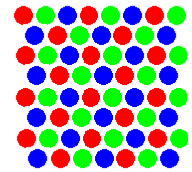
Character-based frame buffer

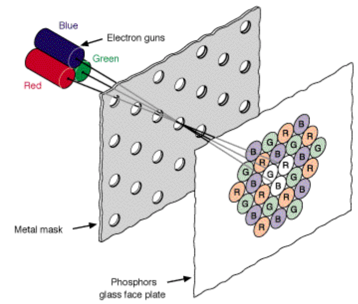


In a raster display the path of the electron beam is hardwired. The computer must synchronize its "painting" of the screen with the scanning of the display. The computer only controls the intensity of the color at each point on the screen. Usually a dedicated section of memory, called the *frame buffer*, is used to store these intensity variations.

Color Video

Delta Electron Gun Arrangement

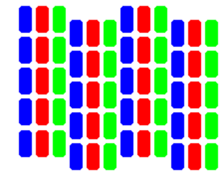




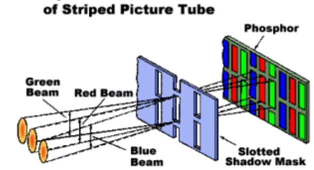
Color CRTs are *much* more complicated

- Requires precision geometry
- Patterned phosphors on CRT face
- Aligned metal *shadow mask*
- Three electron guns
- Less bright than monochrome CRTs

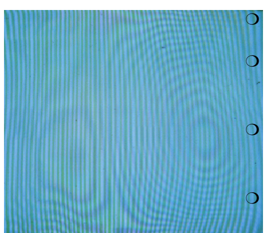
In-line Electron Gun Arrangement



Phosphor Pattern of Striped Picture Tube



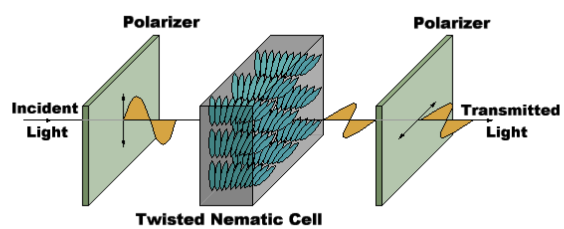
Raster Display



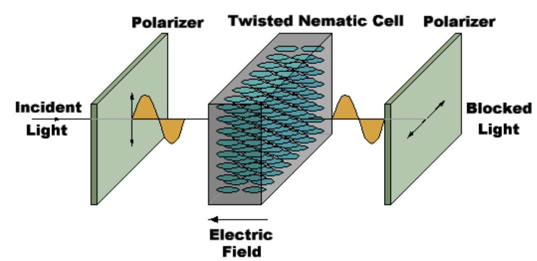
- Disadvantages
  - Requires screen-sized memory array
  - Discrete spatial sampling (pixels)
  - Moire patterns result when shadow-mask and dot-pitch frequencies are mismatched
  - Convergence (varying angles of approach distance of e-beam across CRT face)
  - Limit on practical size (< 40 inches)
  - Spurious X-ray radiation
  - Occupies a large volume
- Advantages
  - Allows solids to be displayed
  - Leverages low-cost CRT H/W (TVs)
  - Whole Screen is constantly updated

Liquid Crystal Displays (LCDs)

Currently, the most popular alternative to the CRT is the Liquid Crystal Display (LCD). LCDs are organic molecules that, in the absence of external forces, tend to align themselves in crystalline structures. But, when an external force is applied they will rearrange themselves as if they were a liquid. Some liquid crystals respond to heat (i.e. *mood rings*), others respond to electromagnetic forces.



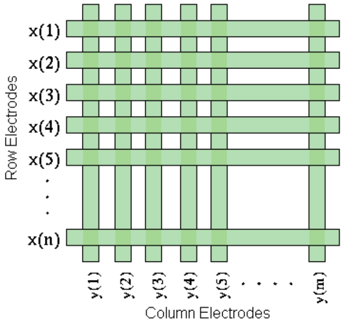
When used as optical (light) modulators LCDs change polarization rather than transparency (at least this is true for the most popular type of LCD called *Super-twisted Nematic Liquid crystals*). In their unexcited or crystalline state the LCDs rotate the polarization of light by 90 degrees. In the presence of an electric field, LCDs the small electrostatic charges of the molecules align with the impinging E field.

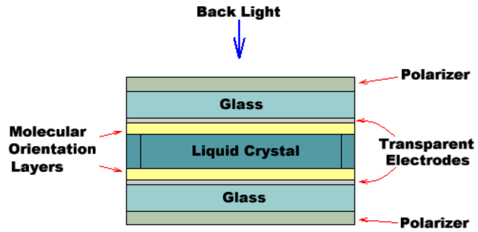


The LCD's transition between crystalline and liquid states is a slow process. This has both good and bad side effects. LCDs, like phosphors, remain "on" for some time after the E field is applied. Thus the image is *persistent* like a CRT's, but this lasts just until the crystals can realign themselves, thus they must be constantly refreshed, again, like a CRT.

The book **Hearns & Baker** is a little confusing in describing how LCDs work (pp. 47-48). They call the relaxed state the "On State" and the excited state the "Off State".

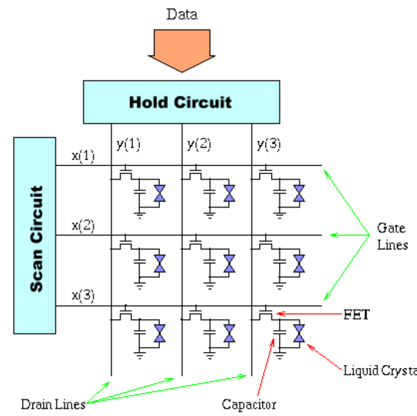
Reflective and Backlit LCDs





Rather than generating light like a CRTs, LCDs act as light values. Therefore, they are dependent on some external light source. In the case of a transmissive display, usually some sort of *back light* is used. Reflective displays take advantage of the ambient light. Thus, transmissive displays are difficult to see when they are overwhelmed by external light sources, whereas reflective displays can't be seen in the dark. You should also note that at least half of the light is lost in most LCD configurations. Can you see why?

Active Matrix LCDs

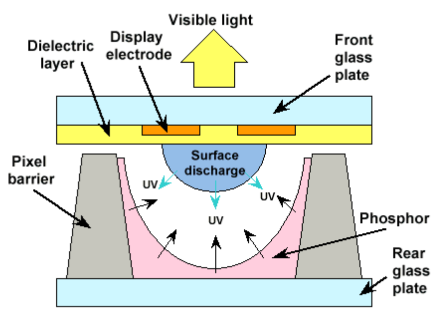


The LCD's themselves have extremely low power requirements. A very small electric field is required to excite the crystals into their liquid state. Most of the energy used by an LCD display system is due to the back lighting.

I mentioned earlier that LCD's slowly transition back to their crystalline state when the E field is removed. In scanned displays, with a large number of pixels, the percentage of the time that LCDs are excited is very small. Thus the crystals spend most of their time in intermediate states, being neither "On" or "Off". This behavior is indicative of *passive displays*. You might notice that these displays are not very sharp and are prone to ghosting. Another way to building LCD displays uses an *active matrix*. The individual cells are very similar to those described above. The main difference is that the electric field is retained by a capacitor so that the crystal remains in a constant state. Transistor switches are used to transfer charge into the capacitors during the scanning process. The capacitors can hold the charge for significantly longer than the refresh period yielding a crisp display with no shadows. Active displays, require a working capacitor and transistor for each LCD or pixel element, and thus, they are more expensive to produce.

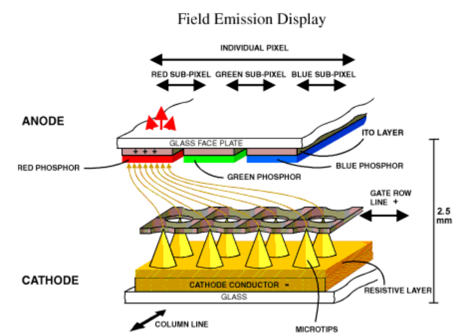
Plasma Display Panels

- Promising for large format displays
- Basically fluorescent tubes
- High-voltage discharge excites gas mixture (He, Xe)
- Upon relaxation UV light is emitted
- UV light excites phosphors
- Large viewing angle



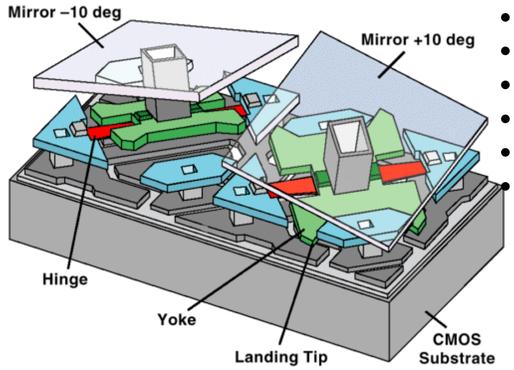
- Less efficient than CRTs
  - Not as bright
  - More power
- Large pixels (~1mm compared to 0.2mm for CRT)
- Ion bombardment depletes phosphors

Field Emission Devices (FEDs)

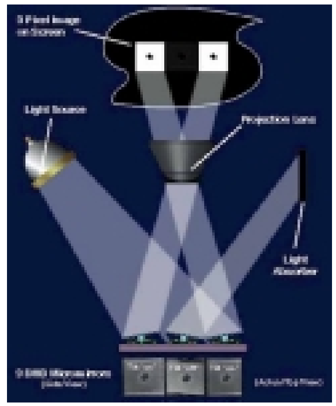


- Works like a CRT with multiple electron guns at each pixel
- Uses modest voltages applied to sharp points to produce strong E fields
- Reliable electrodes proven difficult to produce
- Limited in size
- Thin, and requires a vacuum

Digital Micromirror Devices (DMDs)

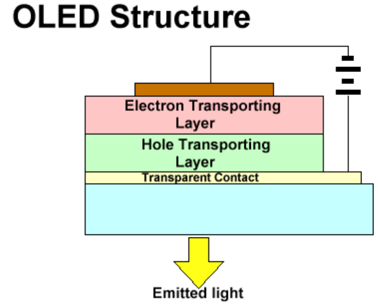


- Microelectromechanical (MEMs) devices
- Fabricated using VLSI processing techniques
- 2-D array of mirrors
- Tilts +/- 10 degrees
- Electrostatically controlled
- Truly digital pixels

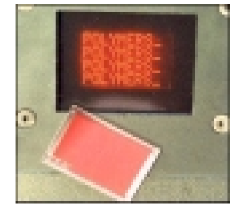


- Suitable only for projection displays
- Gray levels via Pulse-Width Modulation (PWM)
- Color via multiple chips or a color-wheel
- Excellent resolution and *fill-factor*
- Light efficient
- Problems with stray light and flicker

Light Emitting Diode (LED) Arrays

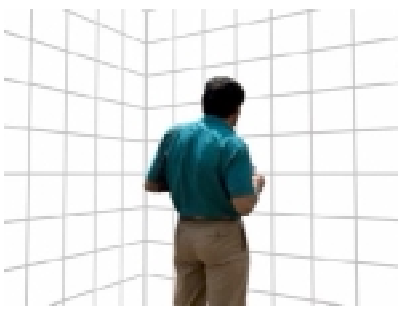


- Organic Light Emitting Diodes (OLEDSs)
- Function is similar to a semiconductor LED
- Thin-film polymer construction
- Potentially simpler processing



- Transparent
- Flexible
- Can be vertically stacked
- Excellent brightness
- Large viewing angle
- Efficient (low power/low voltage)
- Fast (< 1 microsec)
- Can be made large or small
- Tend to breakdown

The Ultimate Display!



There's 3D and then there is 3D 3D 3D 3D

Most often we present 3-dimensional graphics on 2-dimensional displays.

What is the potential for presenting 3D information in a way that it can be percieved as 3D?

Yes, we are talking about holodecks!

Can we build one? How?

Head-Mounted Displays

Consider carrying two displays around on your head.

+ Stereopsis is a strong 3D queue
+ Existing Technology
+ Personal Display
- Obtrusive
- Narrow FOV (Tunnel Vision)
- Low Resolution
- Tracking

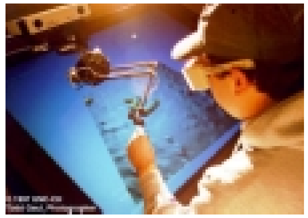
Currently the most popular 3-Dimensional (VR) display

Caves and Fish Bowls

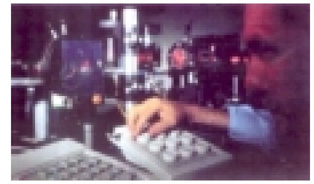
Alternate left and right eye images on a single display

- Electronic shutters
- Polarization
- Red/Green
- Barriers

+Lighter or no headware
+High resolution
-Significant infrastructure
 (5-wall caves have been built)
-Personal
-Still needs tracking



Autostereo Displays

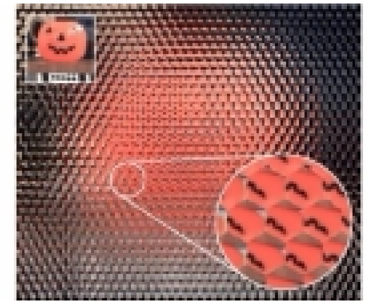


HoloVideo Display

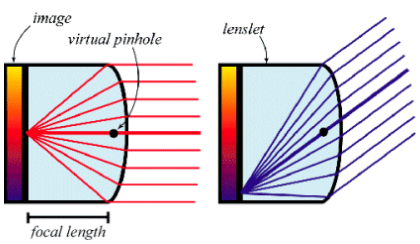
+Multi-viewer
+No Encumberances
-Requires an *extremely* high-resolution
 display element
-Narrow-band illumination

Integral Display

+Multi-viewer
+No Encumberances
+Requires a *moderately* high-resolution
 display
-Requires a dense array of lenses

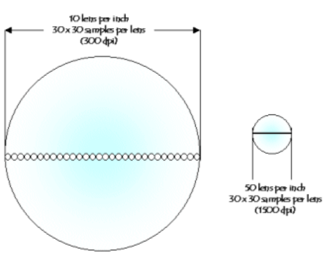


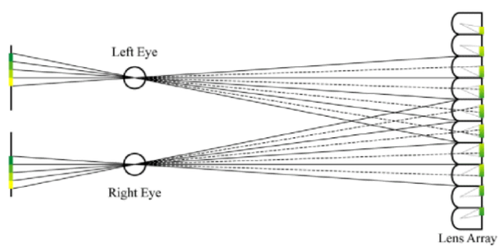
How it Works



Lens Properties

- Plastic hexangonal lens array
- Each lens is a "view dependent" pixel
- Currently 10 lens/inch





More information at: www.graphics.lcs.mit.edu/~aisaksen/projects/autostereoscopic
Paper at: www.graphics.lcs.mit.edu/~aisaksen/projects/drlf