ICS 2311 Computer Graphics

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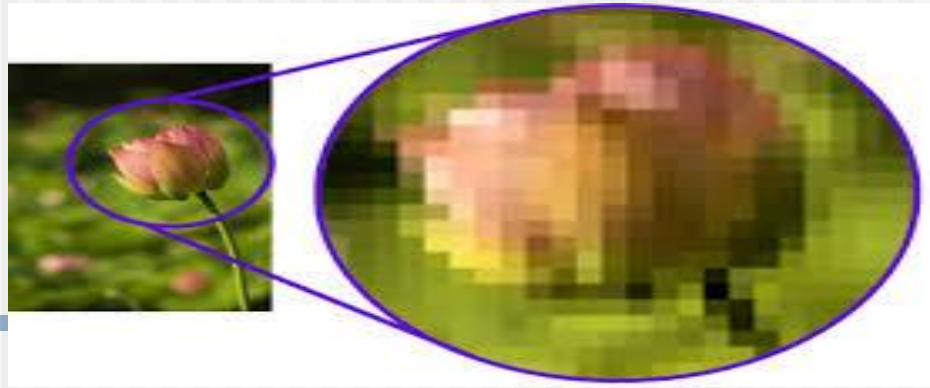
Lesson objective

- **At the end of this class you will**
  - Appreciate the difference between vector and raster graphics
  - Identify the difference between vector and raster file formats
  - Understand the application areas of Vector and Raster graphics
  - Explore the 2D graphics Primitives – More on Raster graphics such Line drawing algorithms, Circle drawing algorithms

Images are Pixels !

- Images are made up of pixels

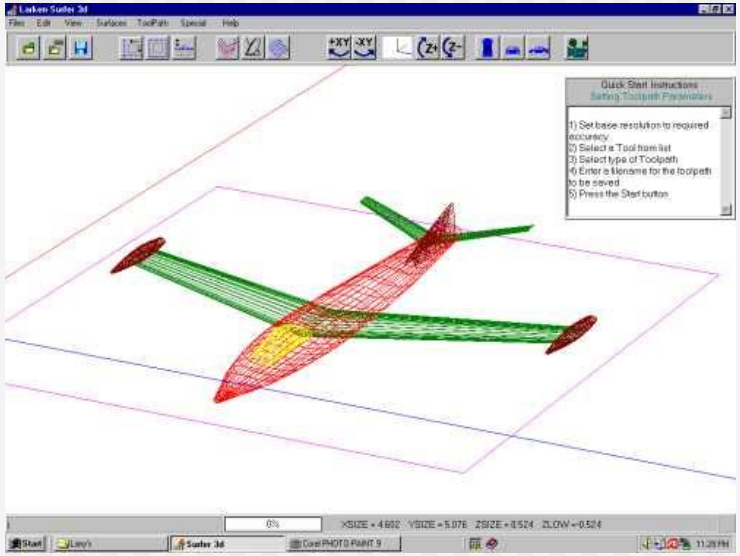
Pixels-2



- **Pixels**: we said it is a portmanteau of pix (from "**pictures**", shortened to "pics") and el (for "**element**") (picture elements) individual squares on a grid that makes up an image. Each square is made up of a color.
- A pixel is the smallest display element that makes up the images seen on a computer monitor or television

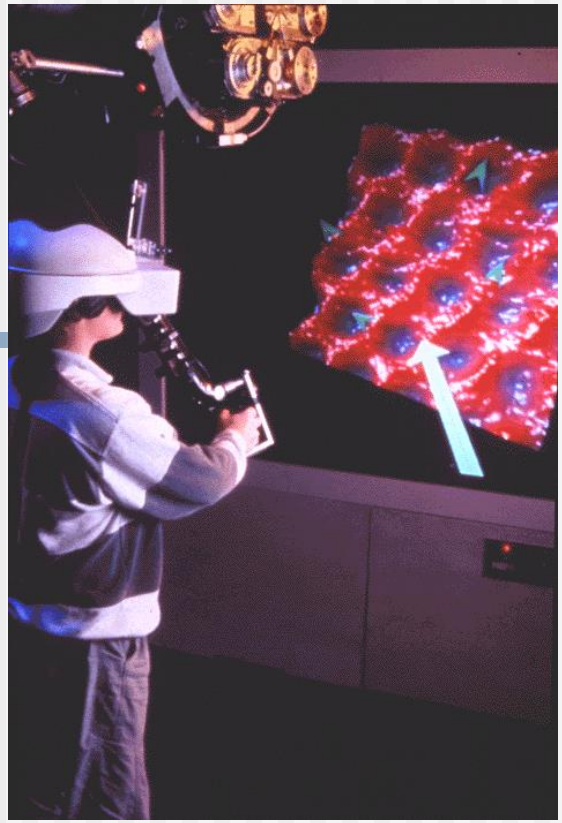
Applications of Computer Graphics

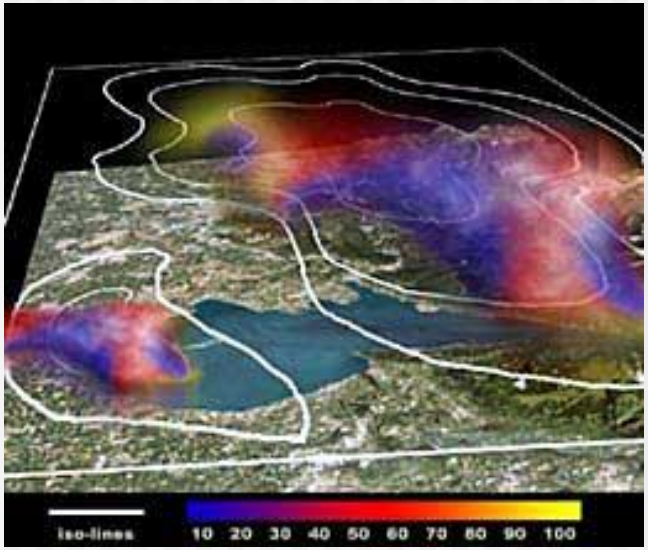
- Computer Aided Design (CAD)
- Why these apps?
  - A: Better conceptualization, interaction, transfer of ideas



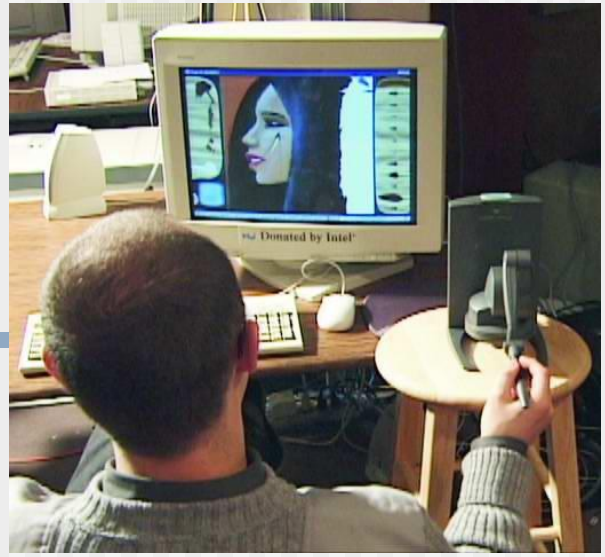
Computer Graphics Applications

- Virtual Reality
  - VR: User interacts and views with a 3D world using "more natural" means
  - Best VR games- Astro bot? Tetris Effect….
  - (multiplatform vs Playstation like Resident Evil7
- Data Visualization
  - Scientific, Engineering, Medical data
  - Visualizing millions to billions of data points
  - See trends
  - Different schemes





Computer Graphics Applications



- Games/Movies
- Disney world?

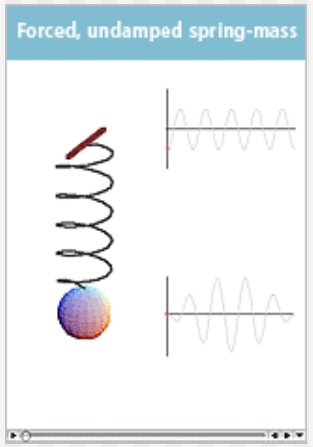
Which ones have you watched? What impressed you about them? Soul? Wolfwalkers? Frozen (1 and 2) ..King Lion Remake(2019)

- Why is Tangled (2010) – the most expensive animation movie?... 260 M USD

Happens in a fictional Corona kingdom !

Rapunzel(Mandy Moore) ..a girl locked by her Protective other..but wants to see the world

Computer Graphics Applications



- Education and Training
  - Models of physical, financial, social systems
  - Comprehension of complex systems
- Computer Art
  - Fine and commercia art
  - Performance Art
  - Aesthetic Computin
  - SIGGRAPH
- Games/Movies

Computer Graphics Applications

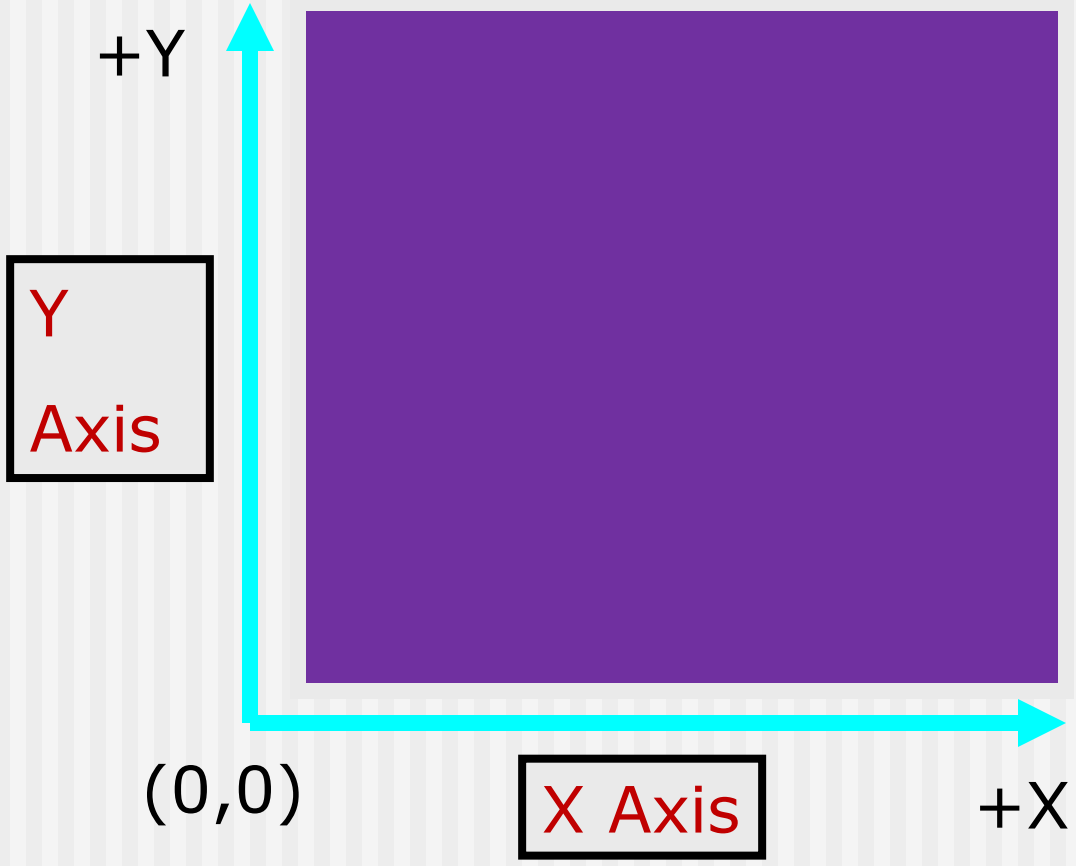
- Image Processing
- Software such as image j, infranview etc
  - ~Inverse of Graphics
  - Start with a picture
  - Process picture information

Overview of Graphics Systems

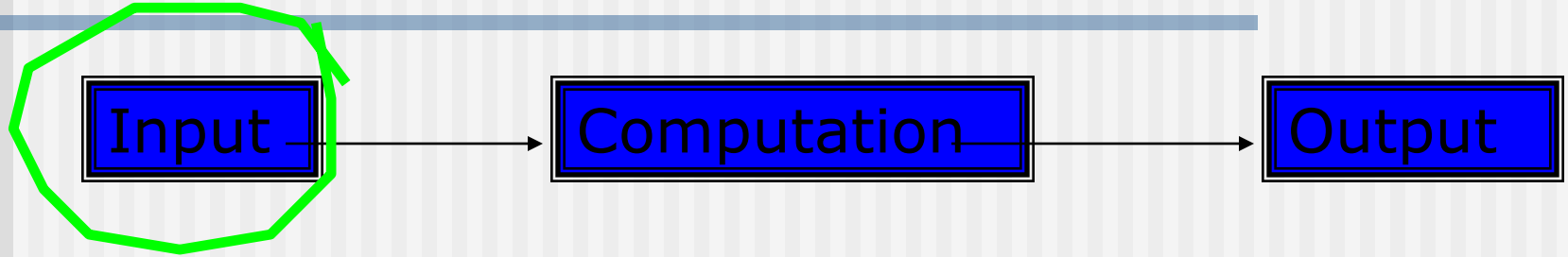
- Images
- Hardware
  - Input Systems
  - Output Systems
- Software
  - **OpenGL**
  - **MAYA**
  - 3D MAX etc

Two Dimensional Images

- Images are two dimensional shapes.
- The two axes we will label as X (horizontal), and Y (vertical).



Hardware Pipeline



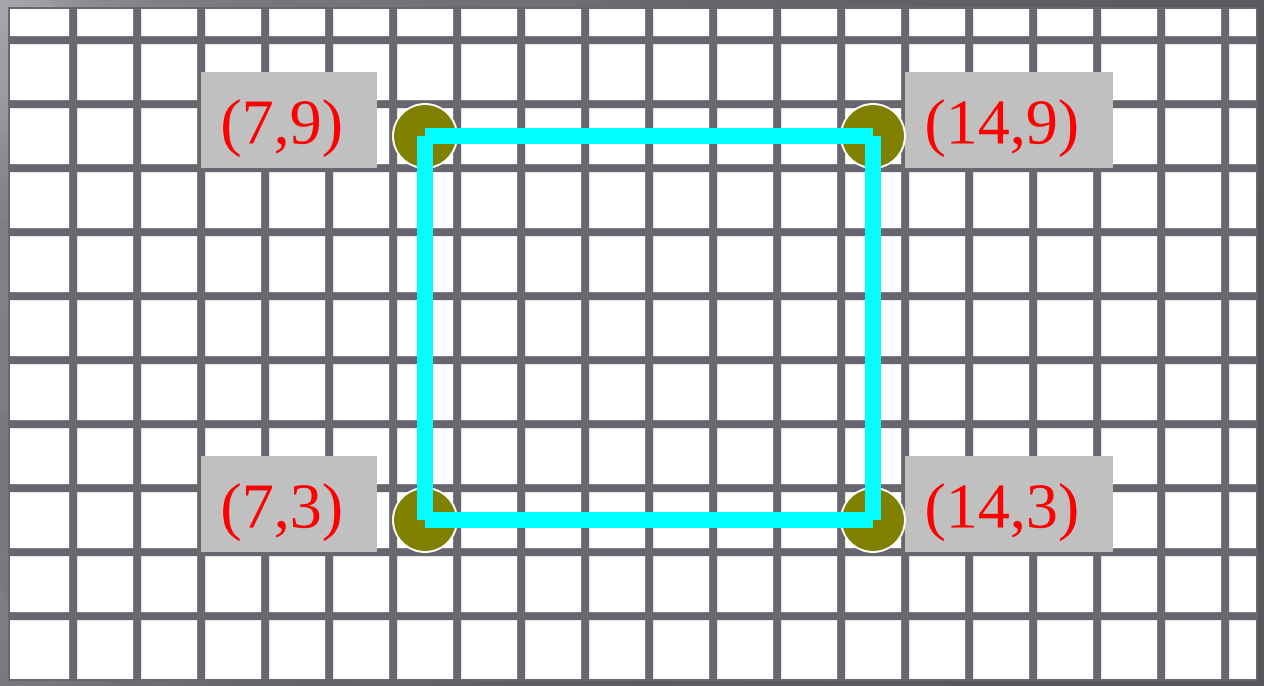
We want to draw a rectangle, how do we describe it to a computer?

Model (n) - object description that a computer understands.

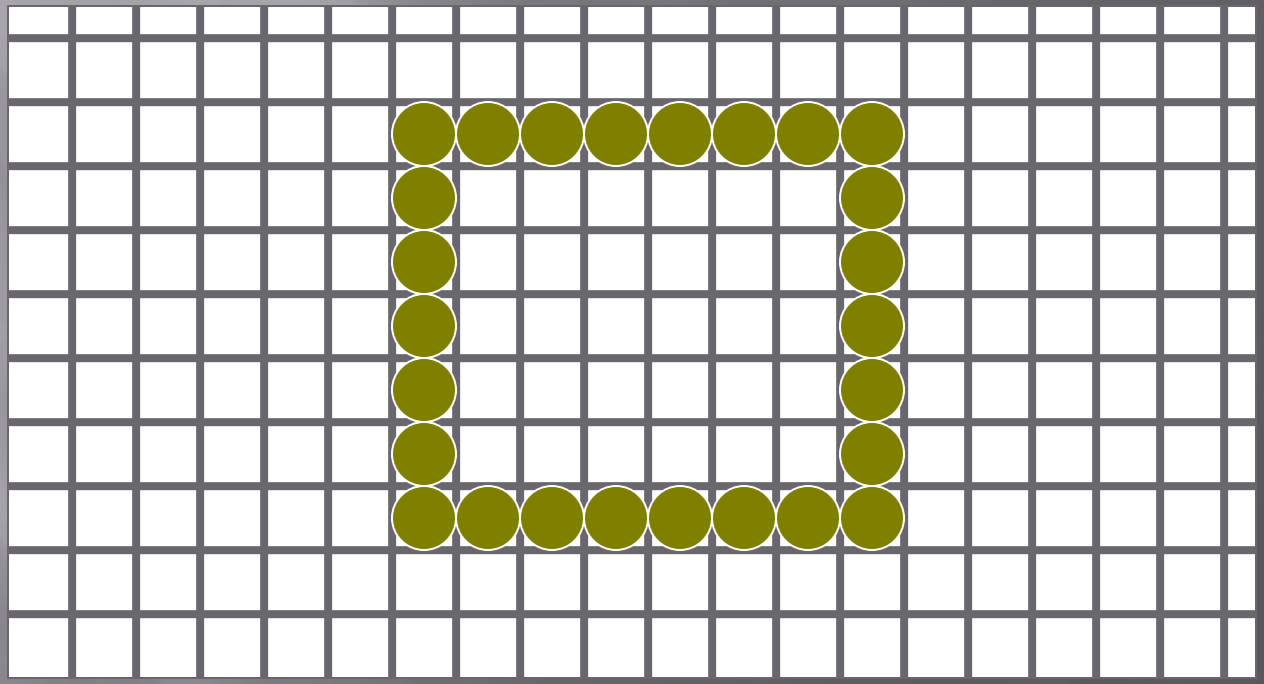
Partition the space

1. Define a set of points (vertices) in 2D space.

2. Given a set of vertices, draw lines between consecutive vertices.



Record every position



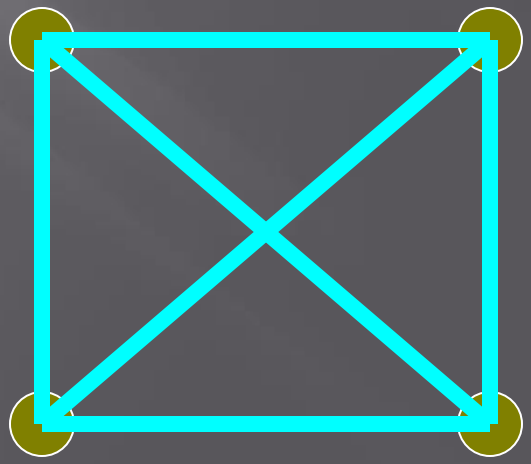
Bitmap - a rectangular array of bits mapped one-to-one with pixels.

Representing Objects

- **Most common method is the VERTEX method. Define the object as a set of points with connectivity information.**
- **Why is connectivity important?**

Connectivity - information that defines which vertices are connected to which other vertices via edges.

Edge – connects two vertices

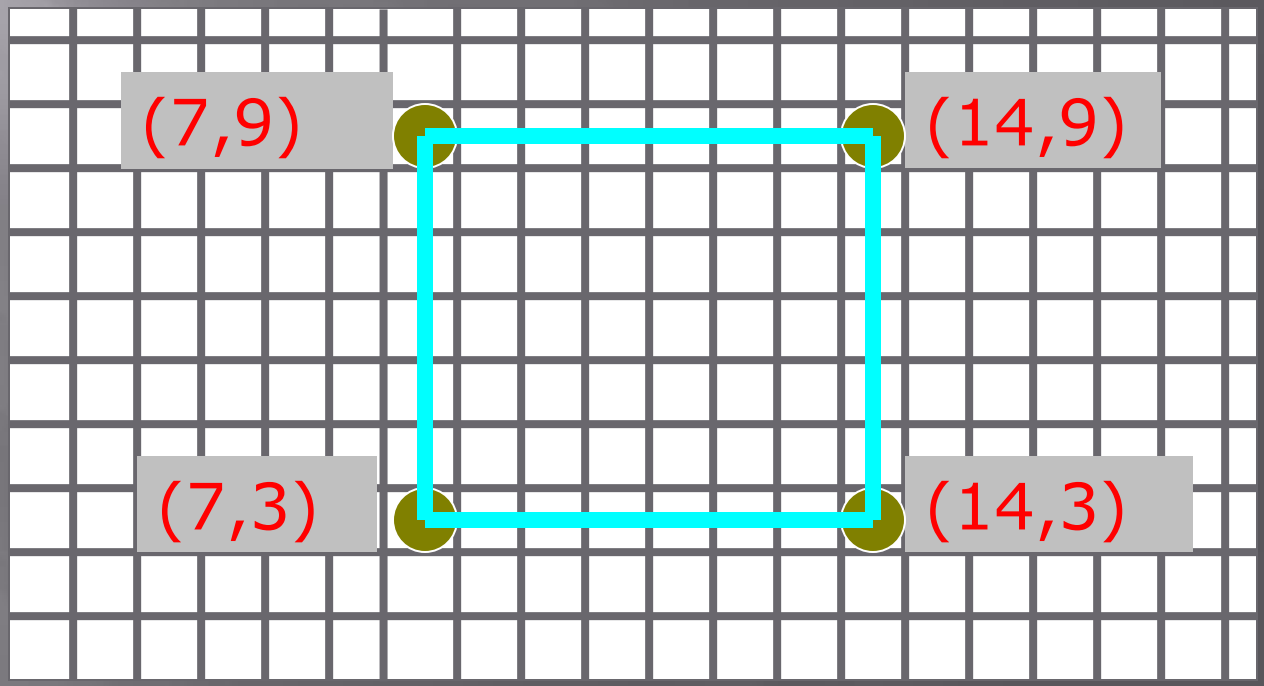


Model file for rectangle

- vert 4 edges 4
- 7 3
- 7 9
- 14 9
- 14 3

vert 4 edges 4

- 1 2
- 2 3
- 3 4
- 4 1



How do we do this? What is needed?

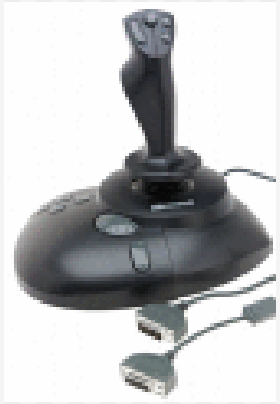
Input Devices

- Locator Devices
- Keyboard
- Scanner
  - Images
  - Laser
- Cameras …..From the basic to complex

Locator Devices-1

When queried, locator devices return a position and/or orientation.

- Mouse (2D and 3D)
- Trackball
- Joystick (2D and 3D)



Locator Devices-2

When queried, locator devices return a position and/or orientation.

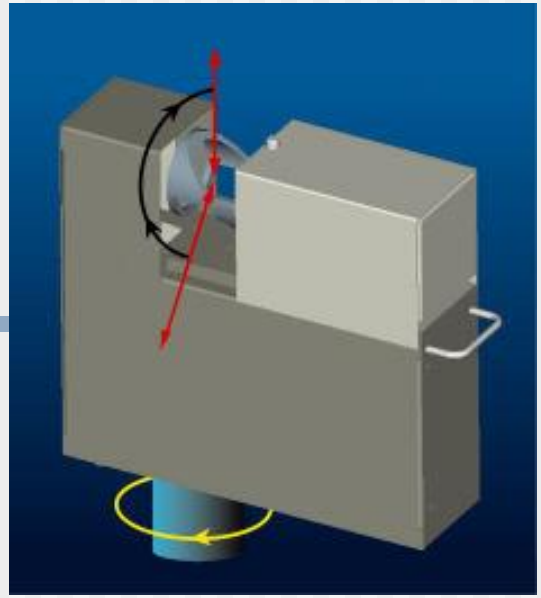
- Tablet
- Virtual Reality Trackers
  - Data Gloves
  - Digitizer

Keyboard

- Text input
  - List boxes, GUI
  - CAD/CAM
  - Modeling

  - Can be specialized or generic use keyboards

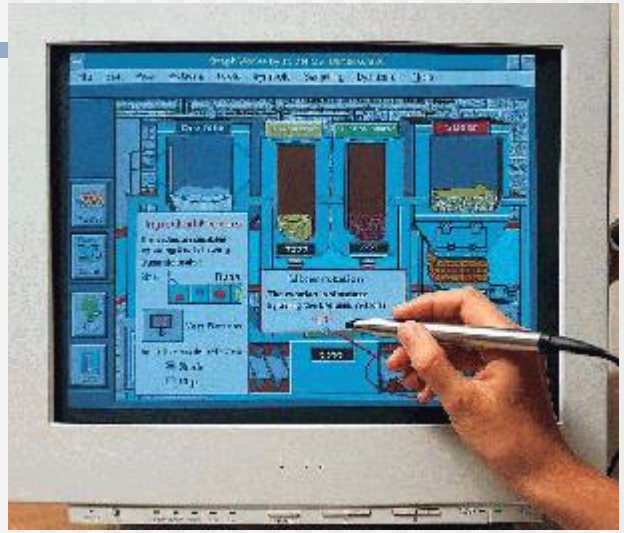
Scanners

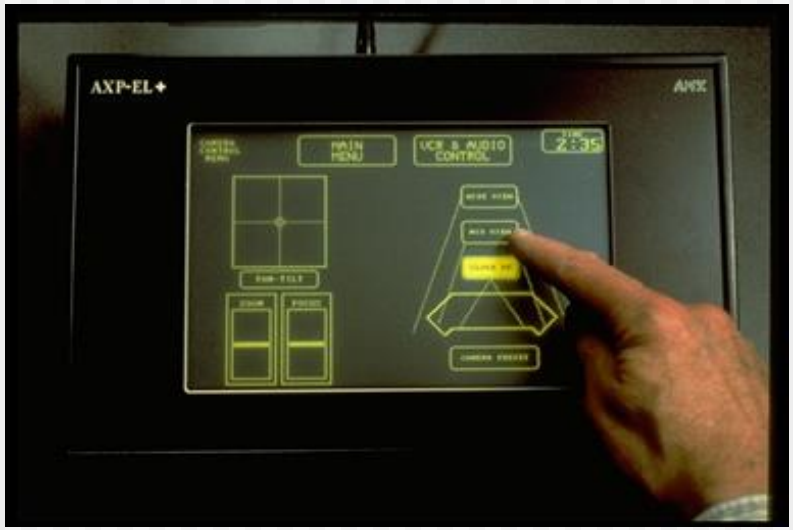


- Image Scanners - Flatbed, etc.
  - What type of data is returned? Bitmap
- Laser Scanners
- Emits a laser and does time of flight. Returns 3D point
- Camera based - research
  - Examine camera image(s) and try to figure out vertices from them.

Other Input devices

- Light Pens
- Voice Systems
- Touch Panels
- Camera/Vision Based
- **Which is best?**
  - **What factors to look into ?**



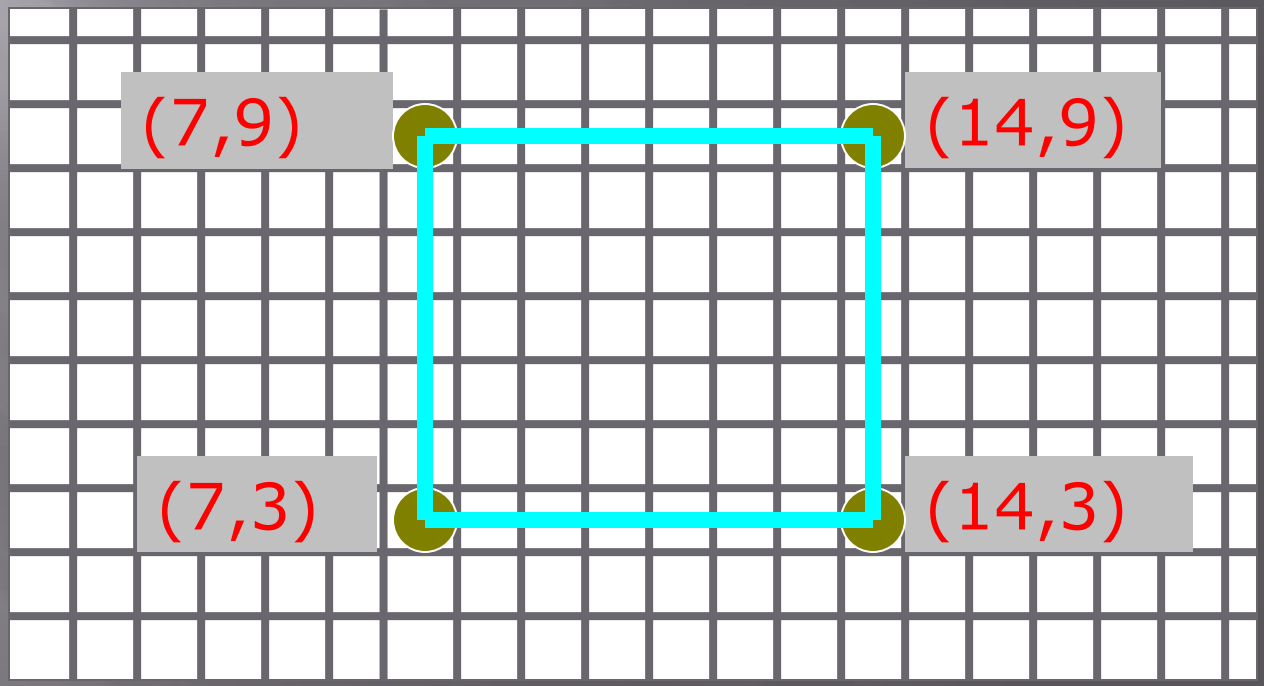


Recap! Model file for rectangle how does a computer do it?

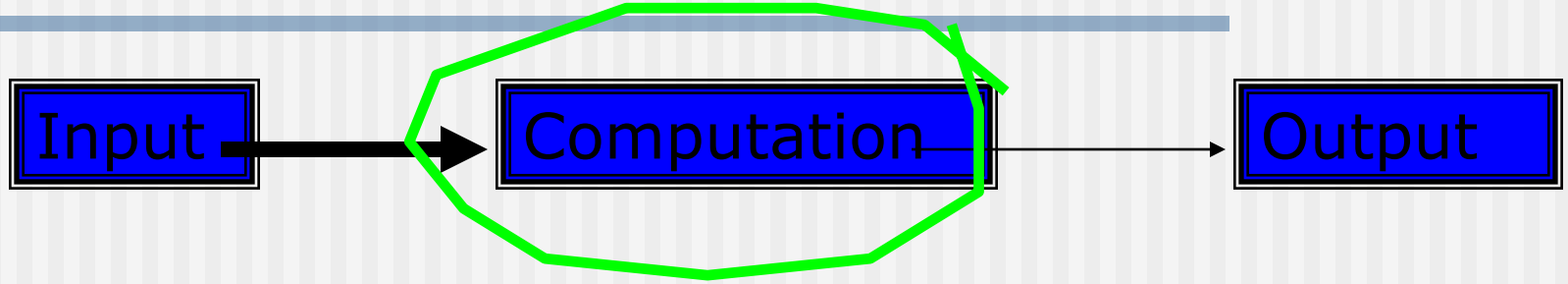
- vert 4 edges 4
- 7 3
- 7 9
- 14 9
- 14 3

vert 4 edges 4

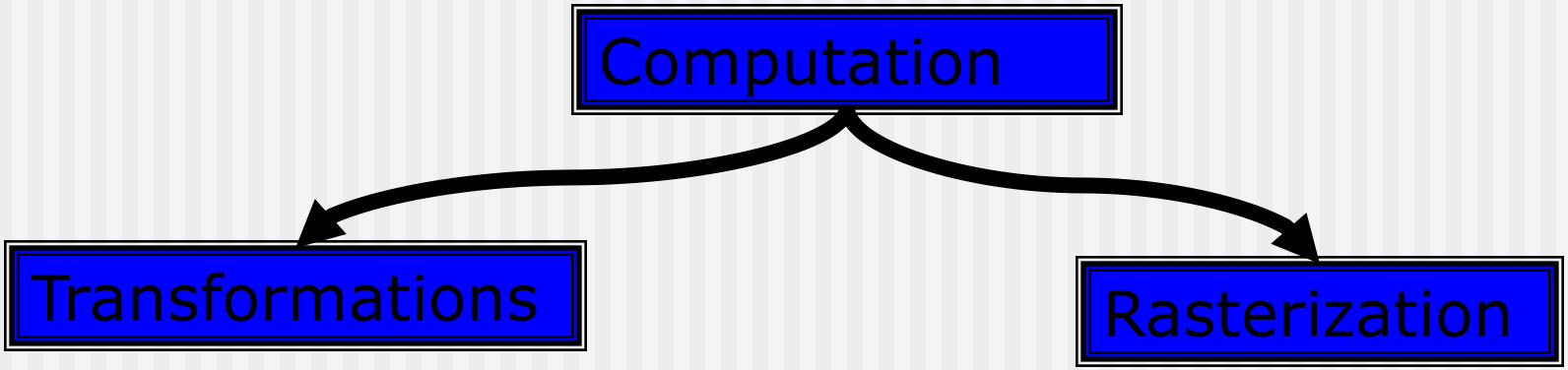
- 1 2
- 2 3
- 3 4
- 4 1



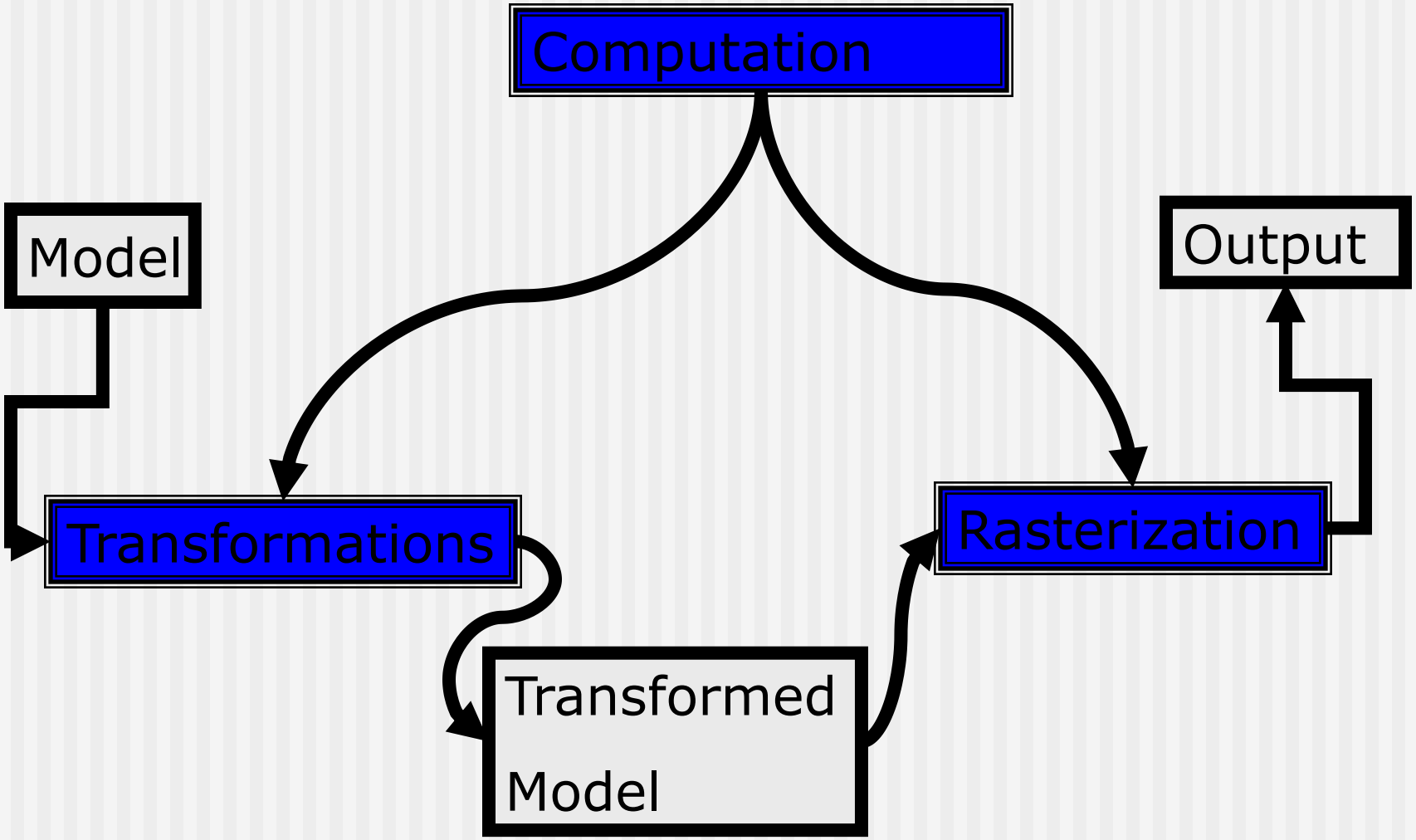
Computation Stage-1



- Now that we have a ***model*** of what we want to draw, what goes on inside the computer to generate the output?



Computation Stage-2



Raster Images vs. Vector Images

Raster (Bitmap) images

- A raster image is made up of **grid of pixels..** In raster images, the more pixels an image contains, the higher its resolution. For example, in a raster image a square is drawn as a grid of pixels (dots) and each of those pixels will have a specific color value.

- **Bitmap images lose their clarity when they are increased in size because the dots get bigger i.e cannot be scaled up without losing quality.**. (**resolution dependent**)

  - **A raster image is resolution-dependant because it contains a fixed number of pixels that are used to create the image .**

- **Common File Formats in Raster : Joint Photographers Expert Group (.JPEG, .JPG) Portable Network Graphics (.PNG)Graphic Interchange Format (.GIF).....TIFF, PSD etc**

- **Raster Editing Programs :AdobePhotoshop, PaintShop, and PhotoPaint all work with pixels (raster images). Gimp (opensource)**

Vector images

- A vector image is defined by objects which are made of lines and curves that are **defined mathematically** in the computer. Vectors can have various attributes such as line thickness, length and color. For example, in a vector image, a square is drawn as four lines connected at the corners. Those lines can be set to different thickness and colors..
- Vector graphics are **resolution-independent**. They can be made larger or smaller without any loss of quality to the image. Vectors can be printed at any size, on any output device, at any resolution, without losing detail and without altering the resolution of the image.
- Vector images are the best choice for typefaces, charts and graphs, drawings, and other graphics that must have sharp lines when scaled to various sizes.

- **Common File Formats in Raster llustrator (.AI), Encapuslated PostScript (.EPS), PostScript (.PS), Scalable vector Graphic .SVG etc**

- **Vectors Editing Programs : PowerPoint, Adobe Illustrator, Inkscape (open source) and Freehand**

Why and when to use Vector or Raster

- solid color objects, manipulated text or many small objects….then **vector** will be the choice
- drop shadows, or other 3D effects, texture or photographs …then **raster** is the best choice

- Both Illustrator AI and EPS formats allow users to place raster images within a vector file. The raster image is not converted to vector format; rather it is simply embedded in the vector file, and is rendered in raster format.

Why and when to use Vector or Raster -2

1) **Type**: does the file format store the type of image you want to use ?
2) **Portability**: can other people use images in this format?
3) **Color Depth**: does the format support the number of colors you need?
    1) **GIF supports 256 Colors (8-bit) , JPEG supports 16.7 M Colors – (24-bit), TIFF supports 16 M colors (24-bit)**
4) **Compression**: can make the file smaller, but it takes time to compress and decompress a file (**GIF supports Lossless compression**
5) **Transparency**: do parts of your image need to be transparent? **Like GIF, PSD supports transparency but JPEG do not**

1. Image Data Types [24-bit color]

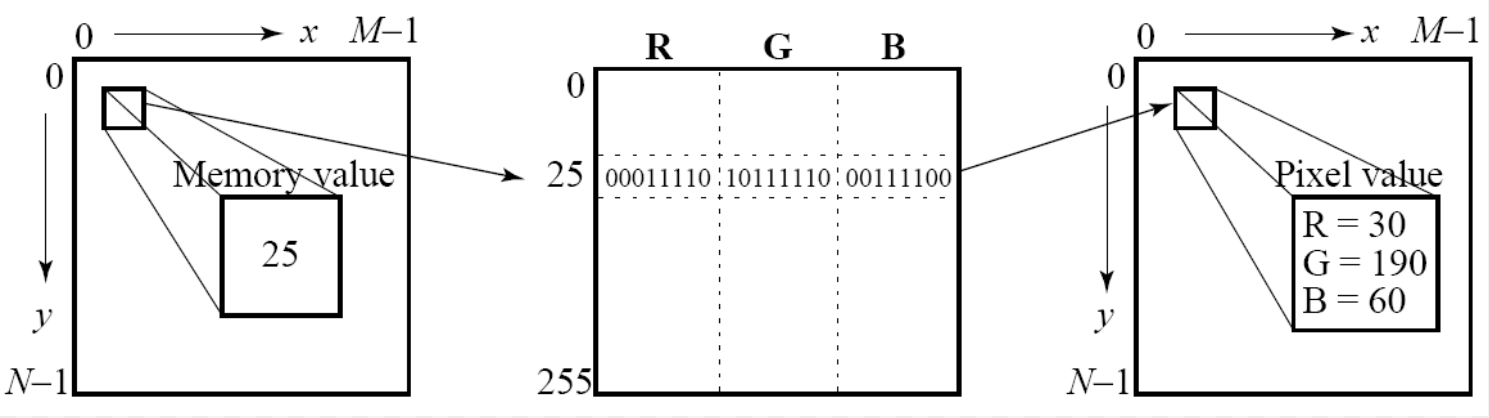
- In a color 24-bit image, each pixel is represented by three bytes, usually representing RGB.
  - - This format supports **256 x 256 x 256** possible combined colors, or a total of **16,777,216** possible colors.
- Many 24-bit color images are usually stored as 32-bit images, with the extra byte of data for each pixel used to store an ***alpha channel /value*** representing special effect information (e.g., transparency)
- Images now have two parts: The image and a mask, called the alpha channel

1.Image Data Types -2 [8-bit color]

- 8 bits of color is also called (“256 colors”)
- In such images a concept of a **lookup table** to store color information is used.
  - - **Basically, the image stores not color, but instead just a set of bytes, each of which is actually an index into a table with 3-byte values that specify the color for a pixel with that lookup table index**.
- E.g Since humans are more sensitive to R and G than to B, we could shrink the R range and G range 0..255 into the 3-bit range 0..7 and shrink the B range down to the 2-bit range 0..3, thus making up a total of 8 bits.
- To shrink R and G, we could simply divide the R or G byte value by (256/8)=32 and then truncate. Then each pixel in the image gets replaced by its 8-bit index and the color LUT serves to generate 24-bit color.

1.Image Data Types -3
Color Look-up Tables (LUTs)

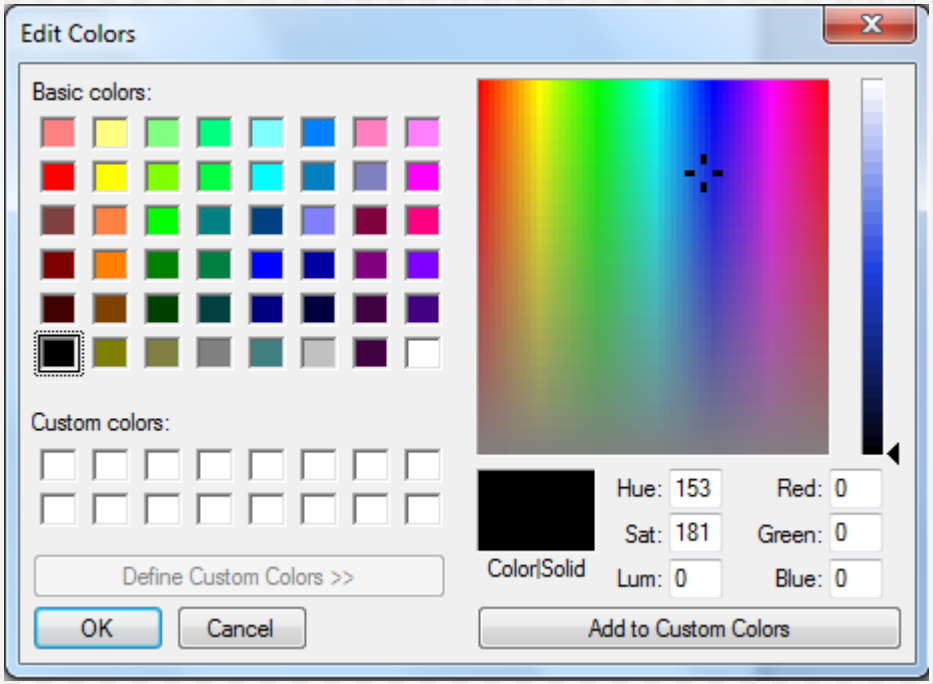
- The idea used in 8-bit color images is to store only the index, or code value, for each pixel. Then, e.g., if a pixel stores the value 25, the meaning is to go to row 25 in a color look-up table (LUT).



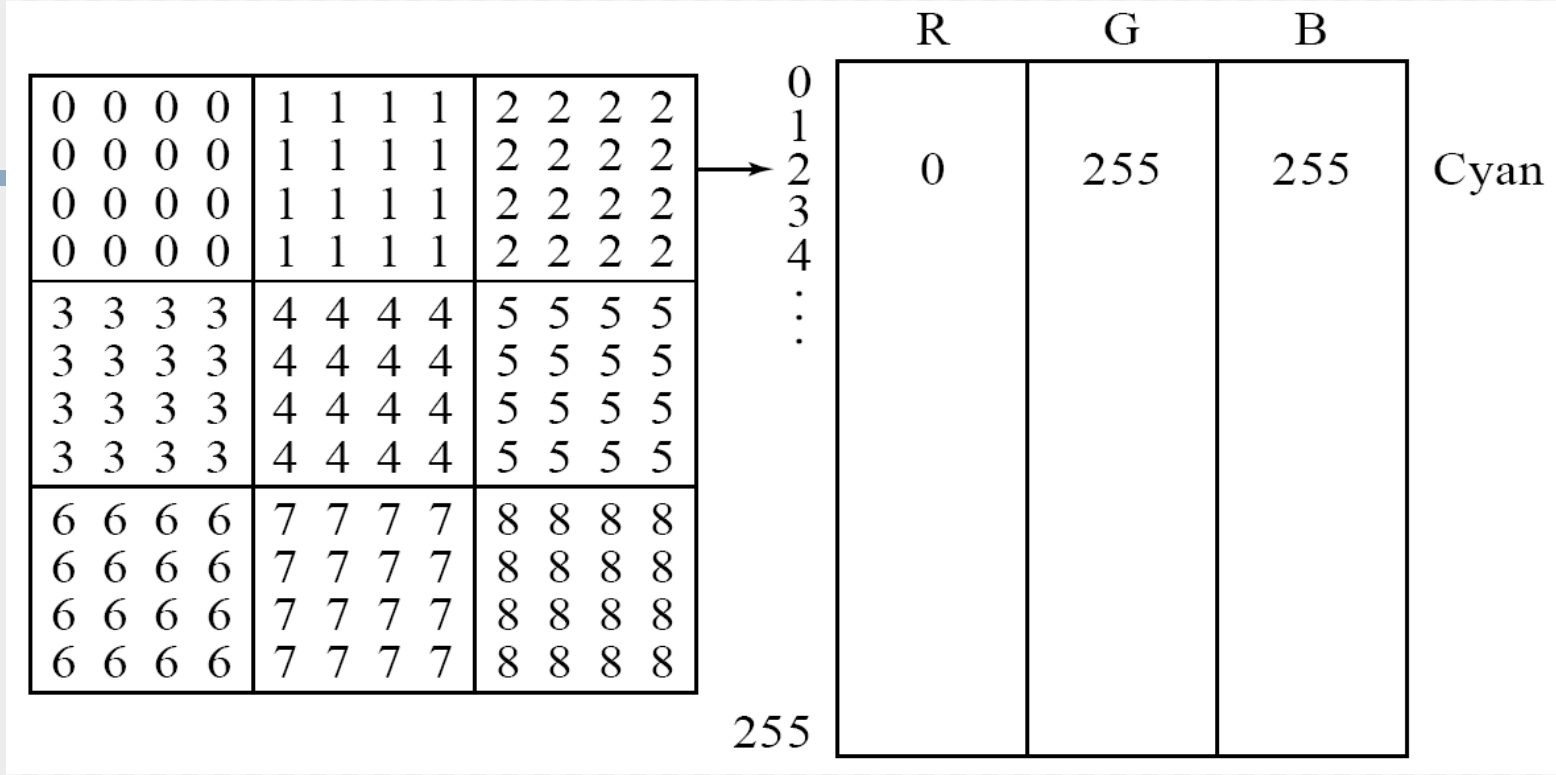
Color LUT for 8-bit color images.

1.Image Data Types -4

- A **Color-picker** consists of an array of fairly large blocks of color (or a semi-continuous range of colors) such that a mouse-click will select the color indicated.
  - In reality, a color-picker displays the palette colors associated with index values from 0 to 255.
  - Figure below displays the concept of a color-picker: if the user selects the color block with index value 2, then the color meant is cyan, with RGB values (0, 255, 255).



1.Image Data Types -5



Color-picker for 8-bit color: each block of the color-picker corresponds to one row of the color LUT

1.Image Data Types -6 [24-bit color VS 8-bit color]

24-bit:

- Each pixel is represented by three bytes (e.g., RGB)
- Supports 256 x 256 x 256 possible combined colors (16,777,216)
- A 640 x 480 24-bit color image would require **921.6 KB of storage**
- Many 24-bit color images are stored as 32-bit images, the extra byte of data for each pixel is used to store an alpha value representing special effect information

8-bit:

- One byte for each pixel
- Supports 256 out of the millions colors possible, acceptable color quality
- Requires Color Look-Up Tables (LUTs) -- *Pallete*
- A 640 x 480 8-bit color image requires 307.2 KB of storage (the same as 8-bit grayscale)

3.Color Depth

- Image formats will only allow a certain number of different colors for each pixel
- The format stores the level of each of the three values for RGB to specify color
- R,G,and B are referred to as *components*
  - ***Red Green Blue***
- *Bit depth* describes the number of colors that can be used in the image

3.Color Depth :Monochrome vs. Grayscale

Monochrome:

- Each pixel is stored as a single bit (0 or 1)
- A 640 x 480 monochrome image requires 37.5 KB of storage.

Grayscale:

- Each pixel is usually stored as a byte (value between 0 to 255)
- A 640 x 480 grayscale image requires over 300 KB of storage.

3.Color Depth :Color codes -RGB-Code

- Black: (0,0,0)
- White: (255,255,255)
- Red: (255,0,0)
- Green: (0,255,0)
- Blue: (0,0,255)

0-255 ….as intensity increases

Hexadecimal RGB-code of significant colours:

Black: #000000
White: #FFFFFF
Red: #FF0000
Green: #00FF00
Blue: #0000FF

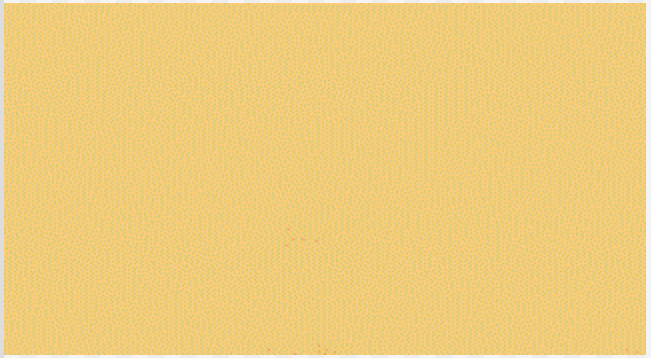
3.Color Depth -When image has more colors than the color depth?

- If the color is not in the palette , the Computer graphics software can choose a separate, close color, or do ***dithering*** (*digital half-toning)*
- ***Dithering*** is where the program fools your eye by creating a pattern of pixels in two colors which makes you see a color between the two
  - *There are various forms of dithering and applications such as Photoshop allows user to select the type of dithering he wants*

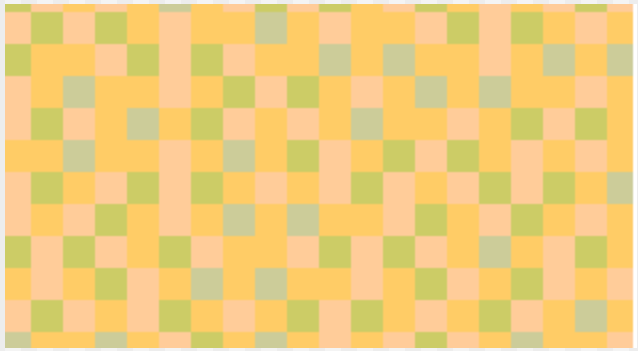
3.Color Depth -Example : Dithering with Color

Color I want to produce

Dithering with only 2 colors, orange and white

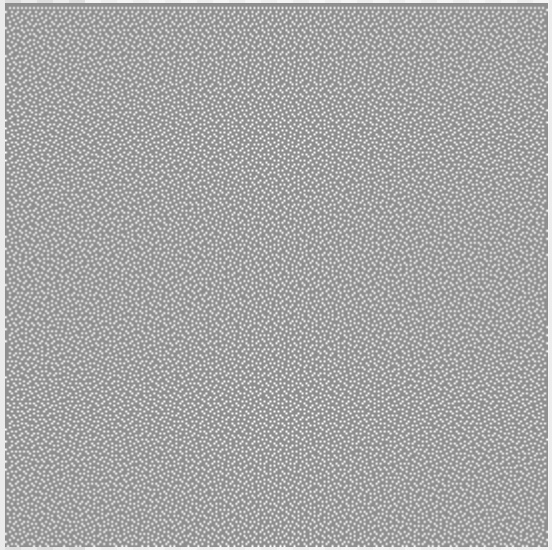


Dithering with all web-safe colors enabled

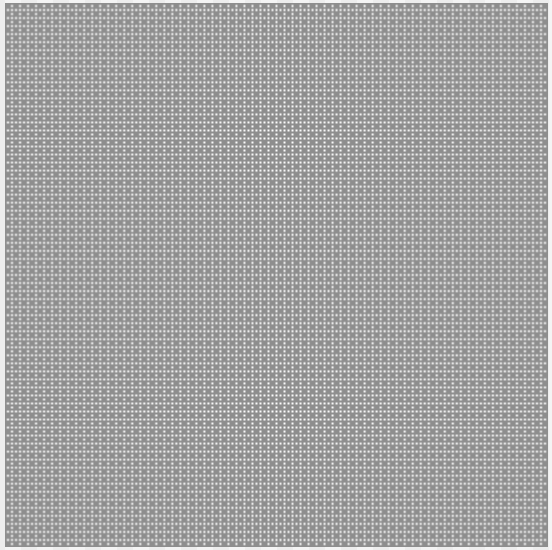


Zoomed View of dithering

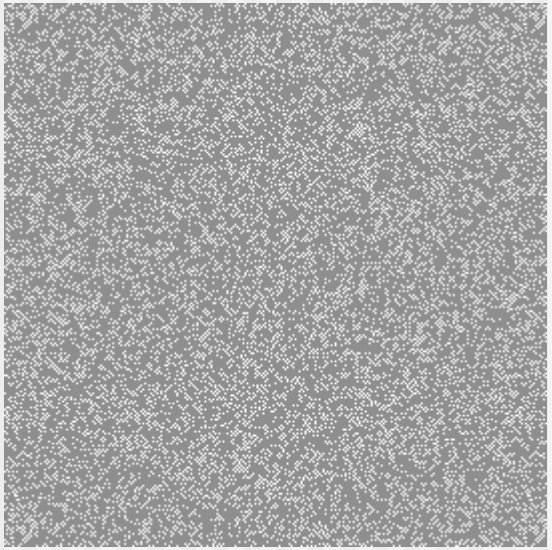
3.Color Depth- Photoshop Dithering Example



Diffusion



Pattern



Noise

3.Color Depth - Bit Depth-1

- **Refers to the number of colors that have been used in an image**.
- 24-bit image allows you to specify up to 2^{24} different colors in your image
  - For each of the RGB values you can specify 2^{8} different values (256 values)
  - 2^{8*3} values for R, for G, and for B gives us 2^{24} different colors
- The "24" in 24-bit says how many bits it takes to store a single color

3.Color Depth - Bit Depth-2

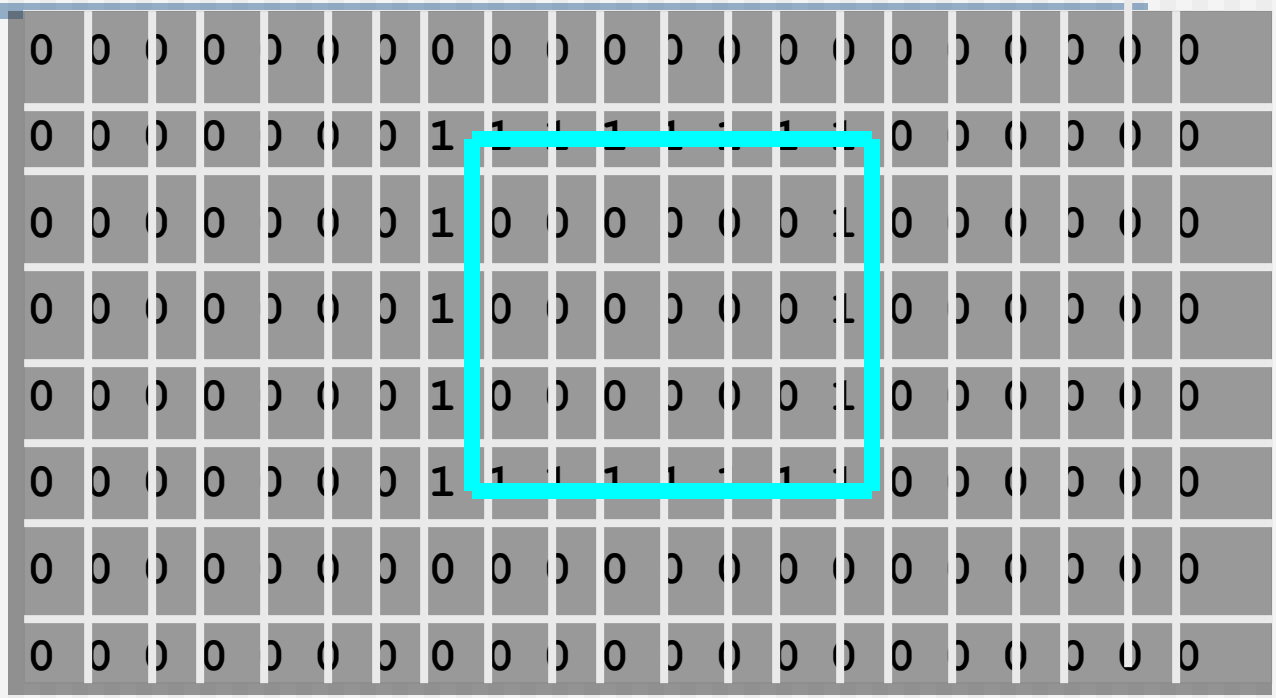
Storage Concept : Frame buffer

Framebuffer - A block of memory, dedicated to graphics output, that holds the contents of what will be displayed.

Pixel - one element of the frame buffer

3.Color Depth – Bit Depth-3

Framebuffer



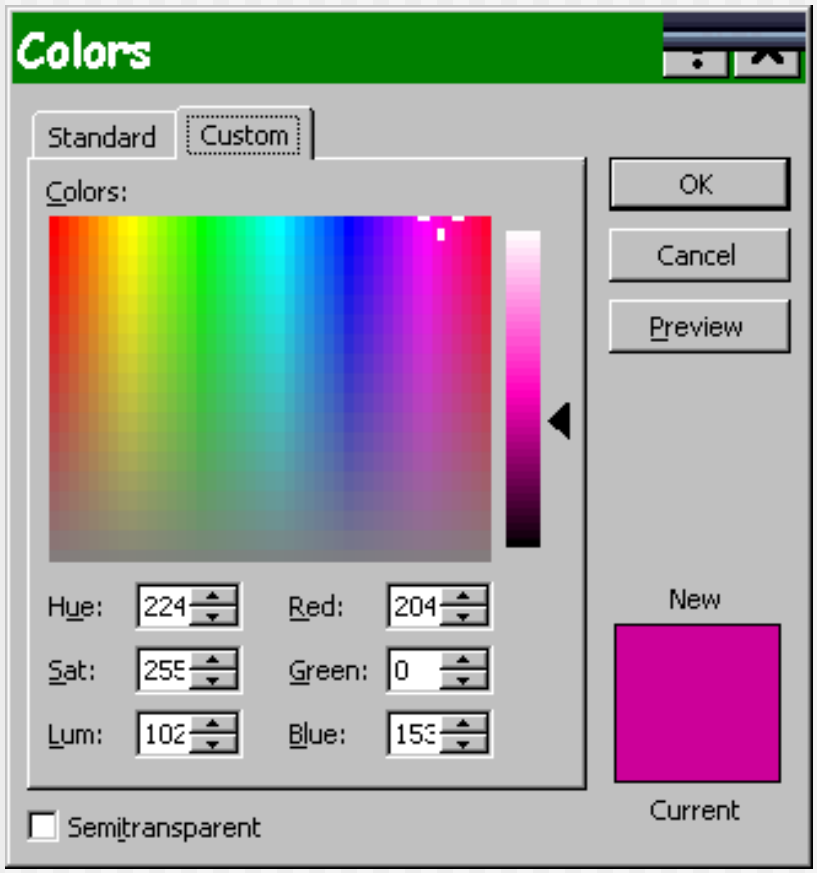
Questions:

How many pixels are there?

How big is the framebuffer?

Framebuffer bit depths

- Remember, we are asking "how much memory do we allocate to store the color at each pixel?"
- Common answers:
  - **16 and 32 bits**



Bit depths

- 16 bits per pixel (high color)
  - 5 bits for red, 5/6 bits for green, 5 bits for blue
  - potential of 32 reds, 32/64 green, 32 blues
  - total colors: 65536
- 32 bits per pixel (true color)
  - 8 bits for red, green, blue, and alpha
  - potential for 256 reds, greens, and blues
  - total colors: 16777216 (more than the eye can distinguish)

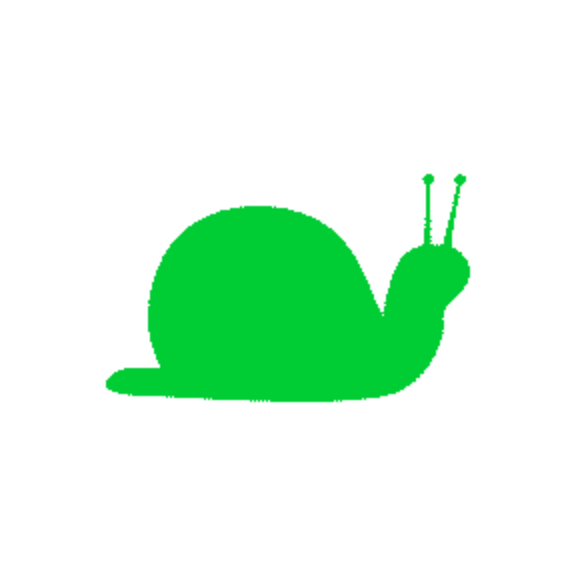
4. Compression

- *Compression* is used to make files smaller
- Bitmap images, especially, can be quite large if stored without compression
  - Ex. A 640 x 480 pixel image with 24-bit color depth would take:
    - 640 * 480*24 bits = 7372800 bits = 900kB
- Windows bmp format is uncompressed not good for usage in websites online as it takes time to load

4. Compression: Lossy vs. Lossless Compression

- There are two main types of compression:
  - *Lossy* and *Lossless*
- When an image is compressed and later uncompressed with a *lossless algorithm*, the image is exactly the same
  - Most common type
  - No information is lost
- *Lossy algorithms* produce images which may be slightly different before compression and after uncompressing
  - Some information may be lost
  - Can produce sometimes produce much smaller files than a lossless algorithm
  - Can be used when the difference isn't very noticeable

5. Transparency : Example of GIF Transparency



- GIF with a white background.
- Unsightly for web pages

- **GIF with a transparent background.**
- **Image is the same size as image on left**
- **But, background shows through**

GIMP and Photoshop support full transparency

The difference between Raster and Vector Graphics

Raster Graphics	Vector Graphics
They are composed of pixels.	They are composed of paths.
In Raster Graphics, refresh process is independent of the complexity of the image.	Vector displays flicker when the number of primitives in the image become too large.
Graphic primitives are specified in terms of end points and must be scan converted into corresponding pixels.	Scan conversion is not required.
Raster graphics can draw mathematical curves, polygons and boundaries of curved primitives only by pixel approximation.	Vector graphics draw continuous and smooth lines.
Raster graphics cost less.	Vector graphics cost more as compared to raster graphics.
They occupy more space which depends on image quality.	They occupy less space.
File extensions: .BMP, .TIF, .GIF, .JPG	File Extensions: .SVG, .EPS, .PDF, .AI, .DXF

Source :https://tinyurl.com/taa5ju7

Resolution

- Resolution refers to the number of pixels in an image, and is a measurement of the output quality of an image, usually in terms of samples, pixels, dots, or lines per inch. Images are displayed on your computer screen at display (or screen) resolution (72 or 96 ppi)..

- Resolution terminology varies according to the intended output device**. PPI (pixels per inch) refers to screen resolution (monitors), DPI (dots per inch) refers to print resolution, SPI (samples per inch) refers to scanning resolution, and LPI (lines per inch) refers to halftone (often newspapers) resolution.**

- Sometimes images are referred to as high resolution (hi-res) or low resolution (lo-res). High resolution would be an image intended for print, generally having at least 300 pixels per inch. Low resolution refers to images only intended for screen display, generally having 72-96 pixels per inch. An image for use on the internet should only be 72 dpi (the minimum display resolution) to minimize download time.

Graphic Card Memory

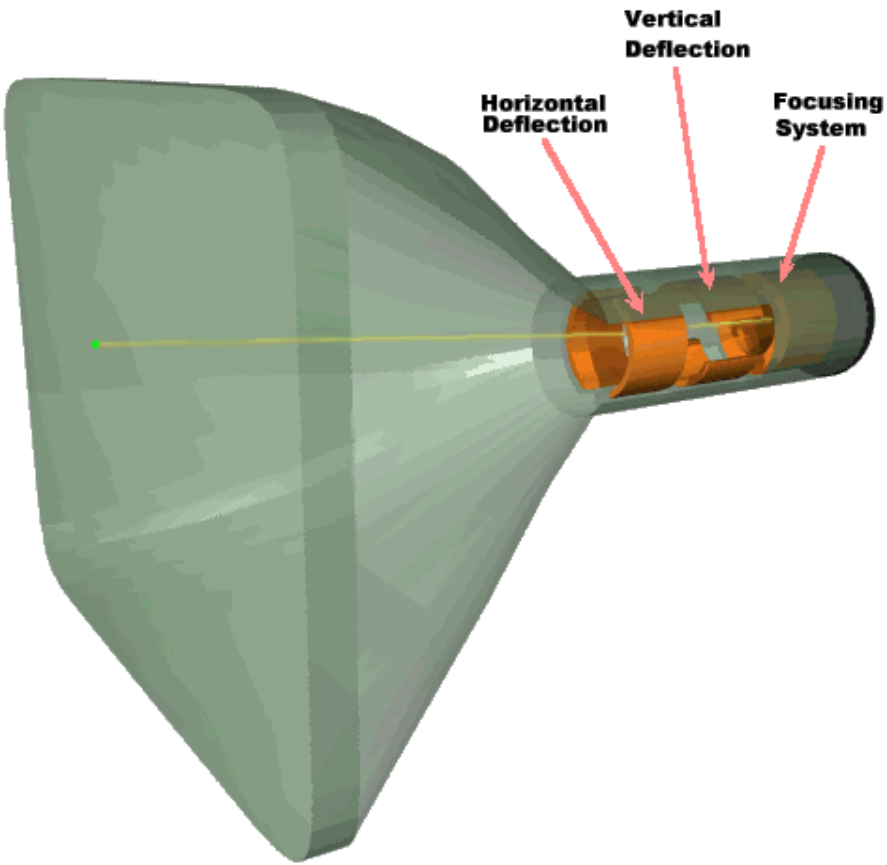
- How much memory is on our graphic card?
  - 640 * 480 * 32 bits = 1,228,800 bytes?
  - 1024 * 768 * 32 bits = 3,145,728 bytes?
  - 1600 * 1200 * 32 bits = 7,680,000 bytes?
- How much memory is on your graphics card?

Raster Displays

- Cathode Ray Tubes (CRTs), most "tube" monitors you see. big and bulky.
- Liquid Crystal Displays (LCDs), there are two types transmissive (laptops, those snazzy new flat panel monitors) and reflective (wrist watches).
- Thin Film Transistors (TFT) ….
- How does GPU **graphics processing unit work? How do they accelerate image processing? What are the trends**

- READING ON How EACH of them works is required

Cathode Ray Tubes (CRTs)



Heating element on the *yolk*.

Phosphor coated screen

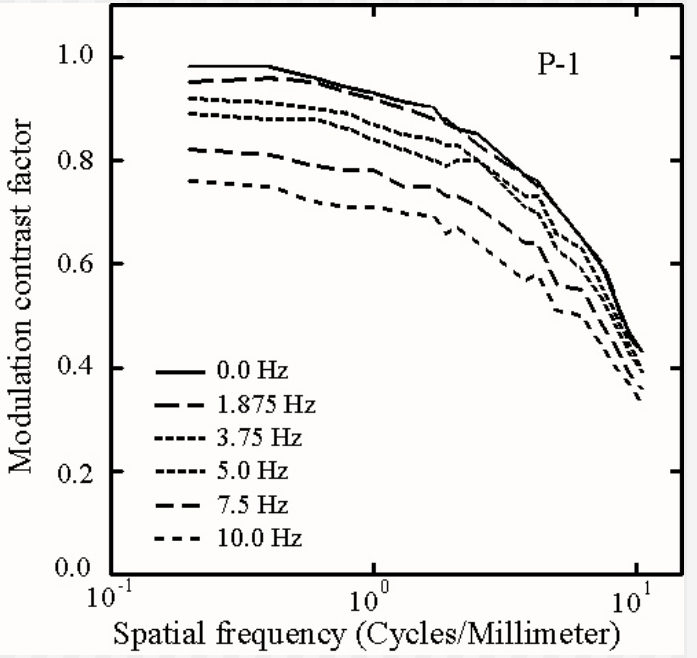
Electrons are boiled off the filament and drawn to the focusing system.

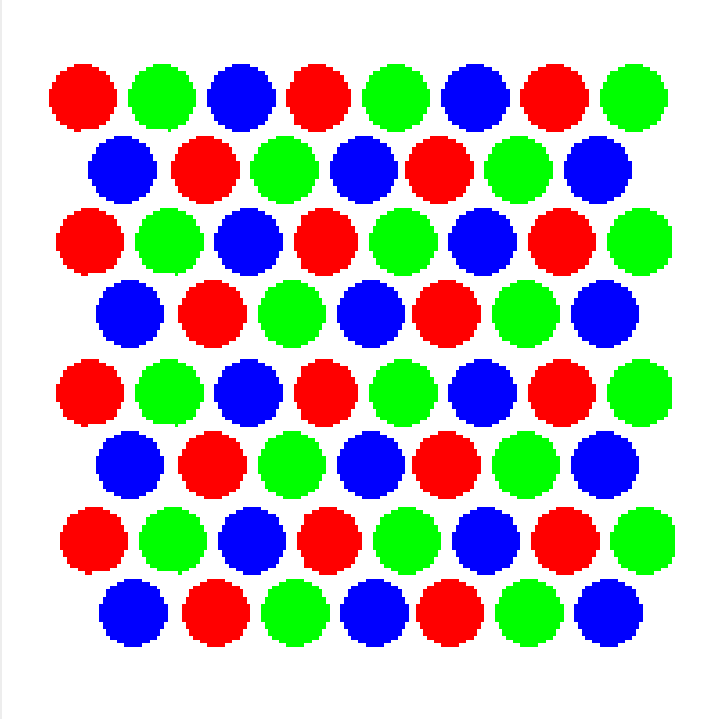
The electrons are focused into a beam and "shot" down the cylinder.

The deflection plates "aim" the electrons to a specific position on the screen.

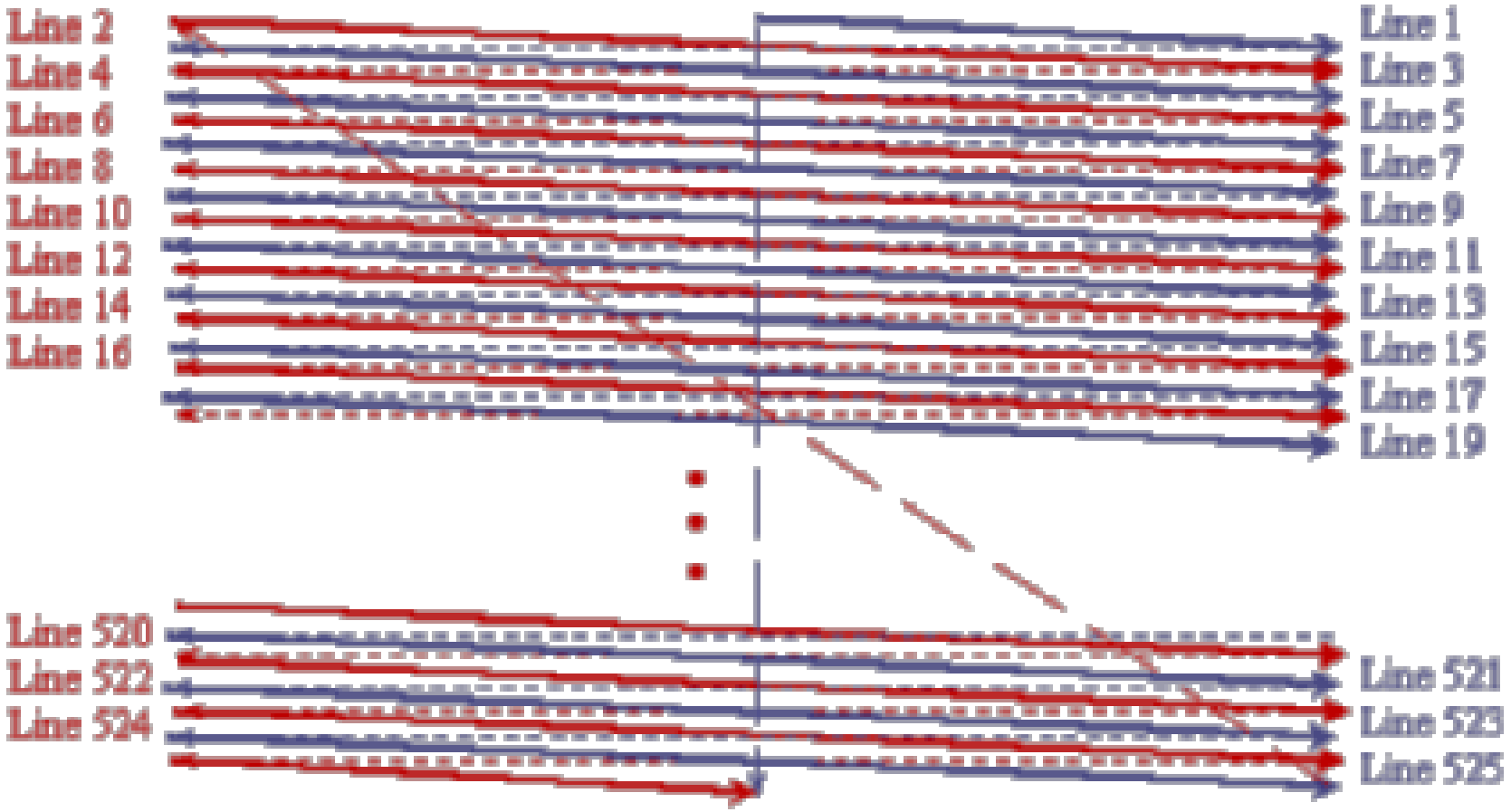
CRT Phosphor Screen

- The screen is coated with phosphor, 3 colors for a color monitor, 1 for monochrome.
- For a color monitor, three guns light up red, green, or blue phosphors.
- Intensity is controlled by the amount of time at a specific phosphor location.





Beam Movement



Beam Movement

scan line - one row on the screen

interlace vs. non-interlace - Each frame is either drawn entirely, or as two consecutively drawn fields that alternate horizontal scan lines.

vertical sync (**vertical retrace**) - the motion of the beam moving from the bottom of the image to the top, after it has drawn a frame.

refresh rate - how many frames are drawn per second. Eye can see 24 frames per second. TV is 30 Hz, monitors are at least 60 Hz.

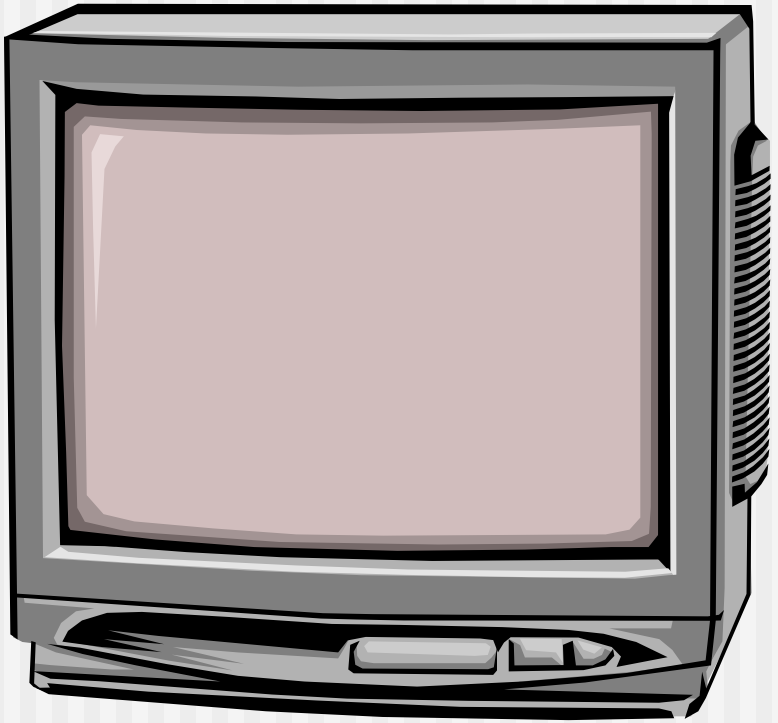
- *Refresh rate* is important, but remember it is different than your program's *update rate*.
- Why is higher, better?

Vector Displays

- Unlike CRTs, vector displays have a single gun that is controlled to draw lines. Think of having a VERY FAST drawing pen.
- Pros: Diagrams/only draw what you need
- Cons: No fill objects/Slows with complexity

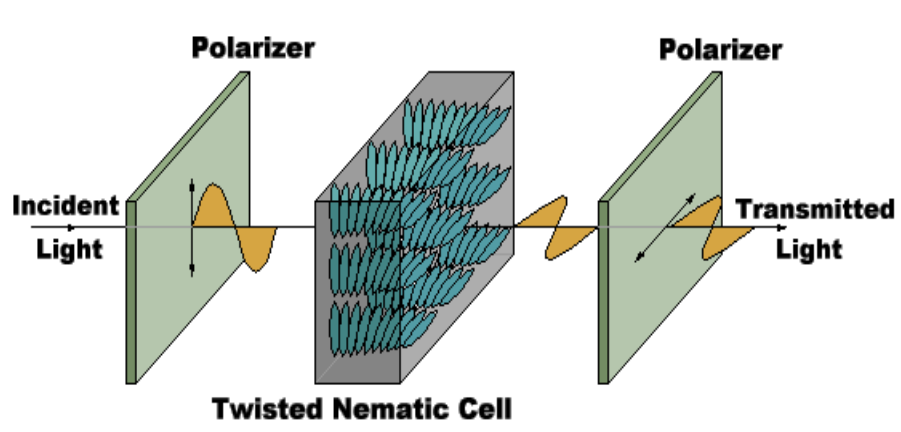
CRTs (cont.)

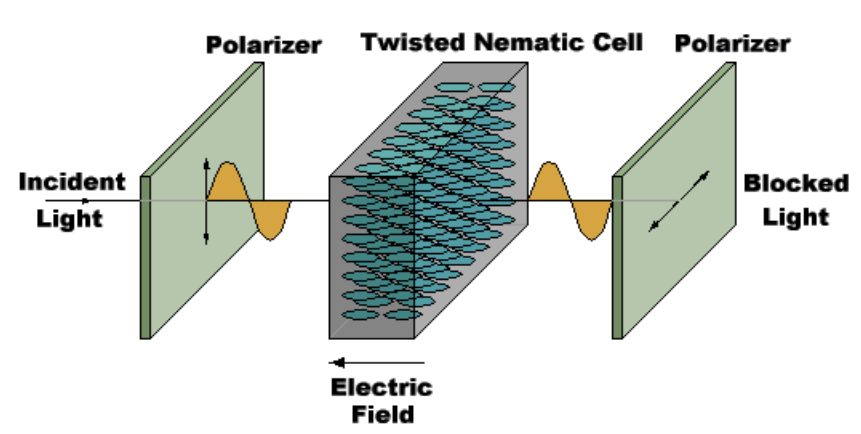
- Strong electrical fields and high voltage
- Very good resolution
- Heavy, not flat



Liquid Crystal Displays (LCDs)

- Also divided into pixels, but without an electron gun firing at a screen, LCDs have cells that either allow light to flow through, or block it.

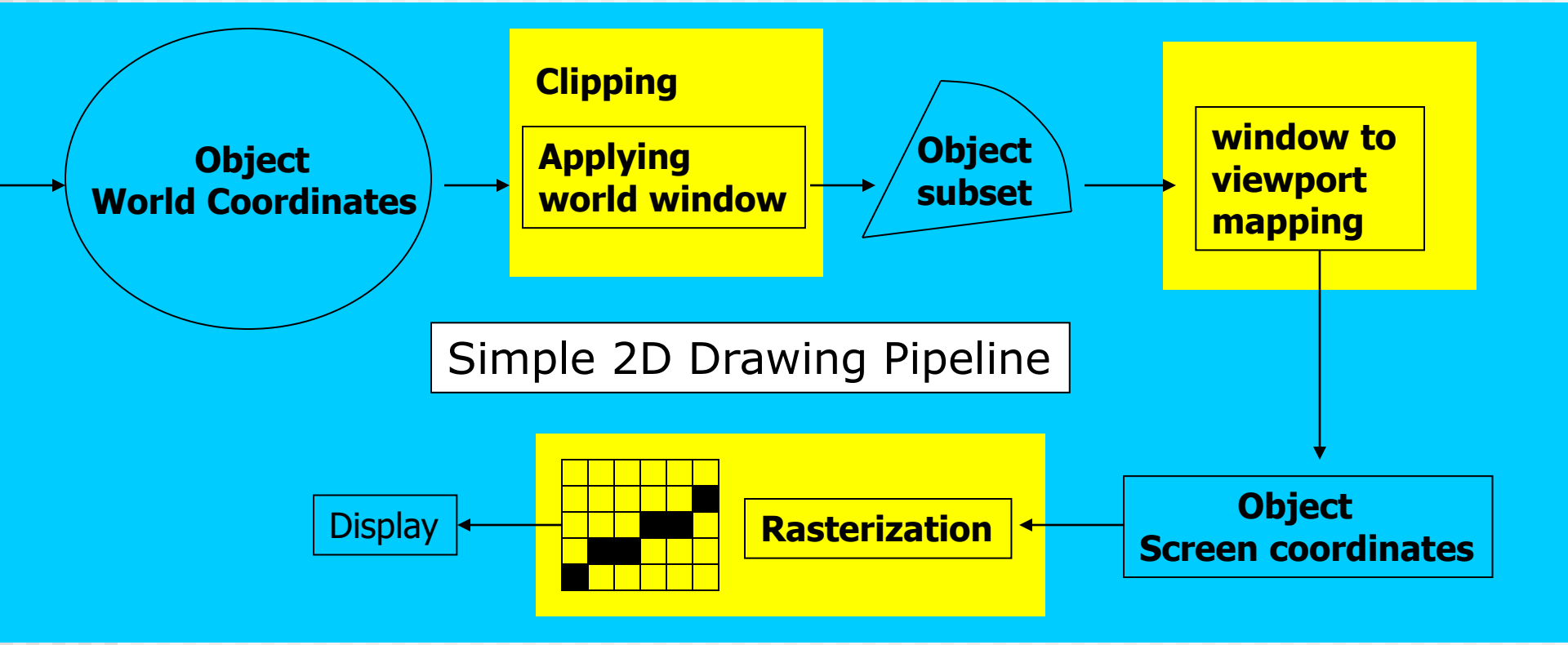




Liquid Crystal Displays

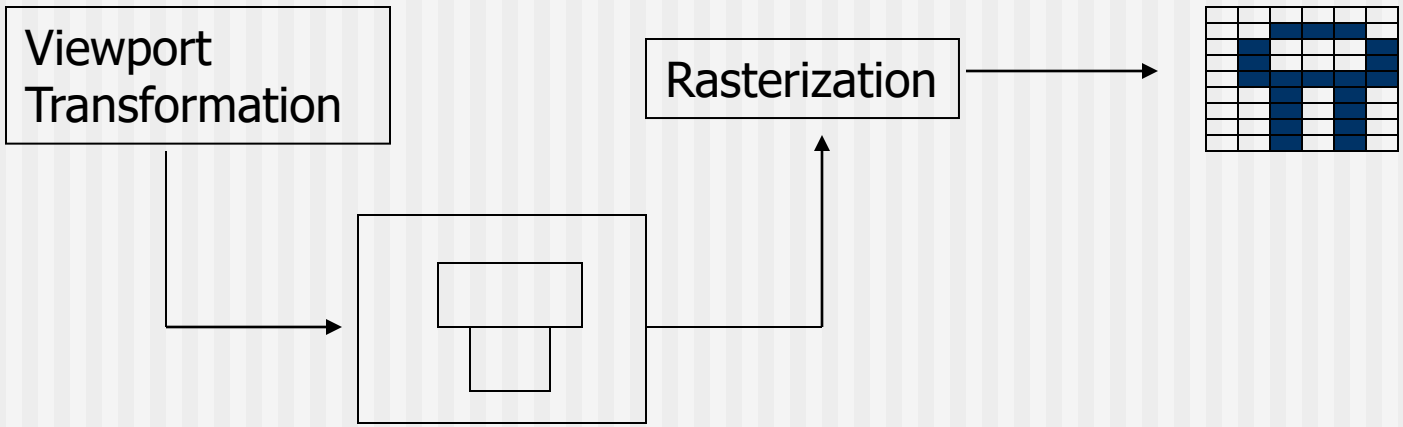
- Liquid crystal displays use small flat chips which change their transparency properties when a voltage is applied.
- LCD elements are arranged in an n x m array call the LCD matrix
- Level of voltage controls gray levels.
- LCDs elements do not emit light, use backlights behind the LCD matrix

2D Graphics Pipeline



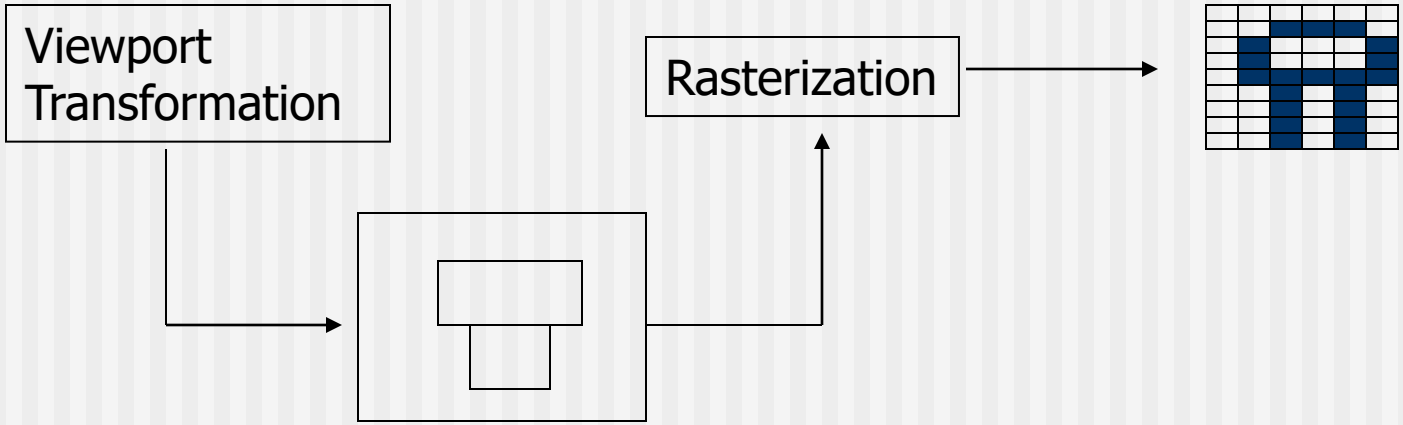
Rasterization (Scan Conversion)

Rasterisation (or **rasterization**) is the task of taking an image described shapes and converting it into series of pixels, dots or lines, which, when displayed together, create the image which was represented via shapes)



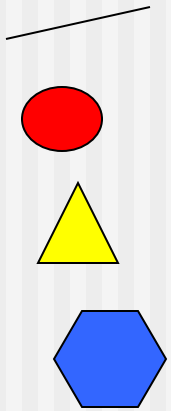
Rasterization (Scan Conversion)

- Convert high-level geometry description to pixel colors in the frame buffer
- Example: given vertex x,y coordinates determine pixel colors to draw line
- Two ways to create an image:
  - Scan existing photograph
  - Procedurally compute values (rendering)



Rasterization

- A fundamental computer graphics function
- Determine the pixels' colors, illuminations, textures, etc.
- Implemented by graphics hardware
- Rasterization algorithms
  - Lines
  - Circles
  - Triangles
  - Polygons



Rasterization Operations

- Drawing lines on the screen
- Manipulating pixel maps (pixmaps): copying, scaling, rotating, etc
- Compositing images, defining and modifying regions
- Drawing and filling polygons
- Aliasing and antialiasing methods

Installing OpenGL

- **Run**: GLinfo2.exe to see your graphic card capabilities(will tell you what OpenGL version your card supports and a list of extensions your card supports)
- **Install Microsoft Visual Studio or your favorite**

IDE (Eclipse, Intellij, Netbeans ….)

- **Install Open GL**
- **Install Glew and Glut**
- **Set project directory settings to link Glut and the IDE**

Installing OpenGL -2

You can get online guidance such as

- https://www.absingh.com/opengl/
- https://sites.google.com/site/gsucomputergraphics/educational/set-up-opengl
- https://www3.ntu.edu.sg/home/ehchua/programming/opengl/HowTo_OpenGL_C.html
- http://cacs.usc.edu/education/cs596/OGL_Setup.pdf
- https://content.byui.edu/file/2315e65e-a34a-48d3-814d-4175a2b74ed5/1/intro/165-opengl-visualStudio2017.html
- http://www.cs.uky.edu/~cheng/cs633/OpenGLInstallGuideWindows.pdf

- END of Lecture 1