Computer Graphics
(4190.410)

신 영길

2008. 3. 4

Syllabus

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Syllabus

- Textbooks
  - D. Hearn and M.P. Baker, *Computer Graphics, 2nd Ed,* Prentice Hall
  - D. Hearn and M.P. Baker, *Computer Graphics with OpenGL*, 3rd edition, Prentice Hall
  - *Direct X Course material*
- Pre-requisites
  - Knowledge on C++ programming
- This syllabus and all subsequent information on the course will be available using the WWW.
  - The home page : http://cglab.snu.ac.kr/lectures/08-1/graphics

Syllabus

- The goal of this course
  - Introduction to the theory and practice of computer graphics
- Grading policy
  - Midterm Exam: 30%
  - Final Exam: 40%
  - Assignments (3 to 5): 30%
    - Penalty for late assignments : 10% per day

Covered Topics

Week 1	Graphics introduction
Week 2	Scan conversion and clipping
Week 3	Windows Programming I Sampling
Week 4	Windows Programming II 2D & 3D Geometric transformation
Week 5	2D viewing DirectX : Creating a device and rendering vertices
Week 6	Modeling & 3D Viewing
Week 7	3D viewing **Mid-term exam**
Week 8	Hidden surface removal DirectX : Using matrices
Week 9	Lighting and shading
Week 10	DirectX : Lighting Color
Week 11	Curve and surfaces
Week 12	Curve and surfaces DirectX : Texture Mapping
Week 13	GUI DirectX : Fixed and programmable pipeline
Week 14	**Final exam**

Why we use images/pictures?

- “One picture is better than a thousand words”
- Vision is the most important sense of humans
- Humans communicate well with images

What is Computer Graphics?

- Computer graphics generally means creation, storage and manipulation of models and images
- Such models come from diverse and expanding set of fields including physical, mathematical, artistic, biological, and even conceptual (abstract) structures

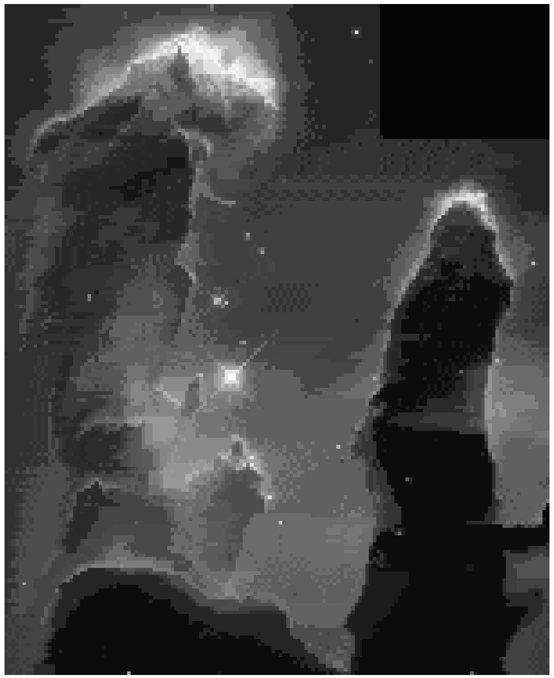
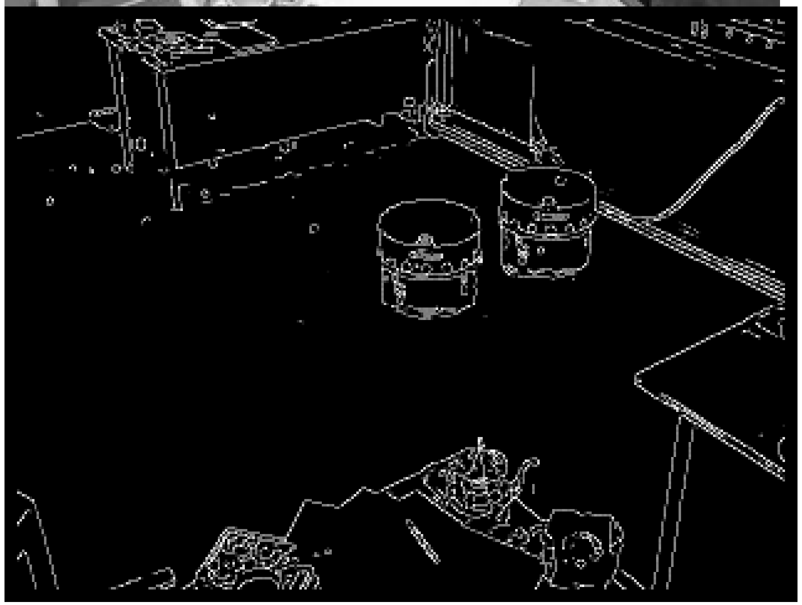


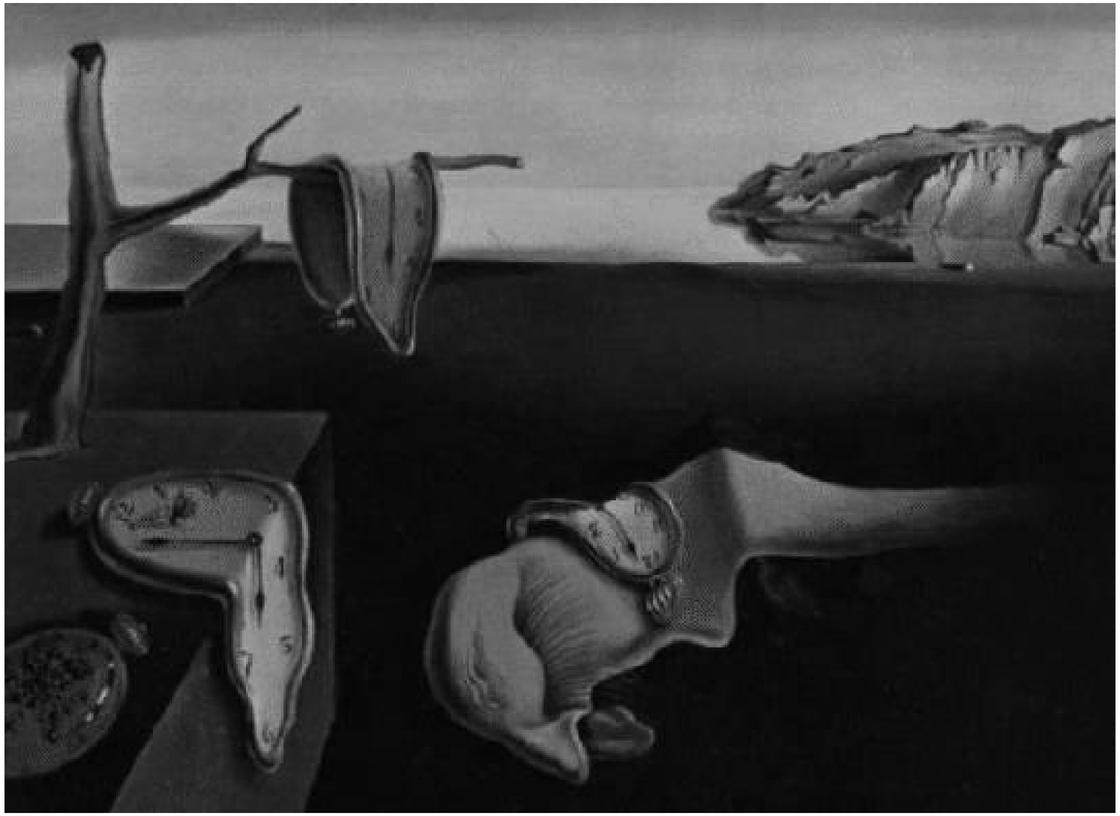
Image Processing & Computer Vision

- Digital Image Processing
  - Techniques to transform an image into a meaningful signal
- Image Analysis (Computer Vision)
  - Extracting symbolic information from the image.

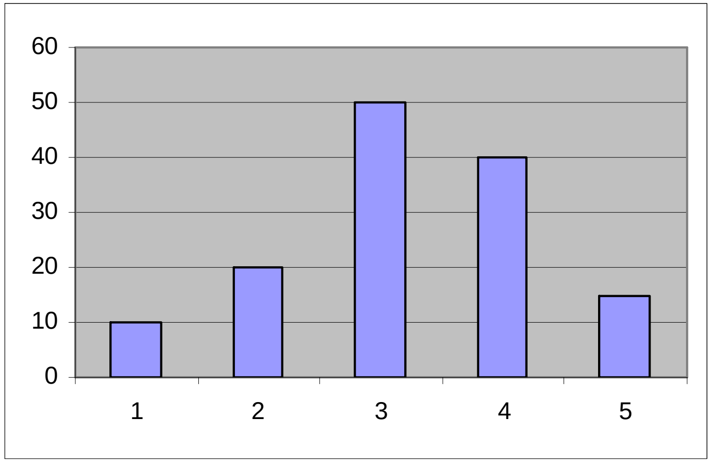


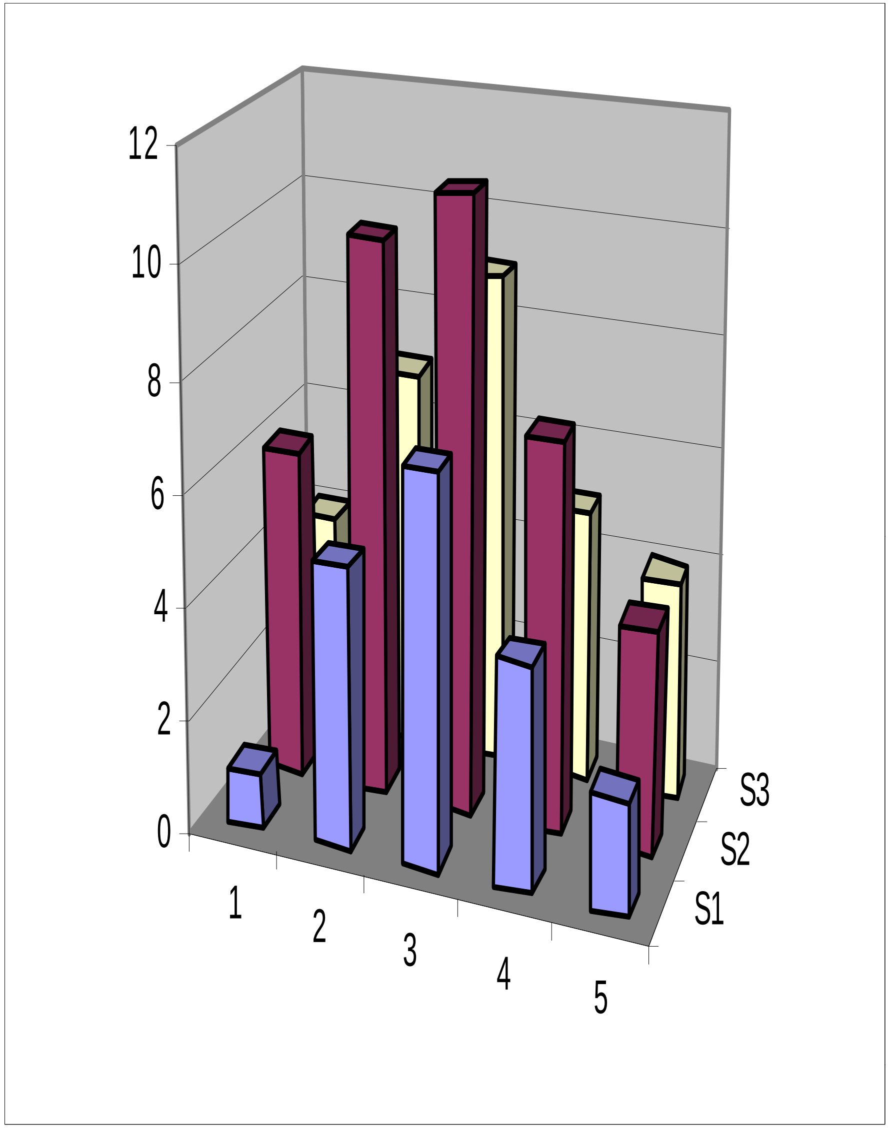
Applications

- Showing photos, pictures

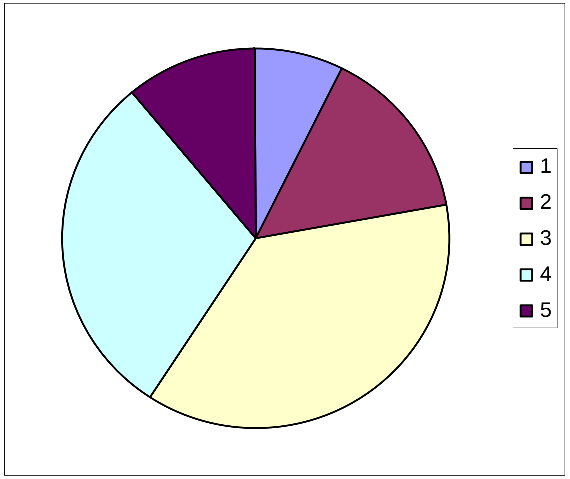
 

- Presenting information
  - Bar charts

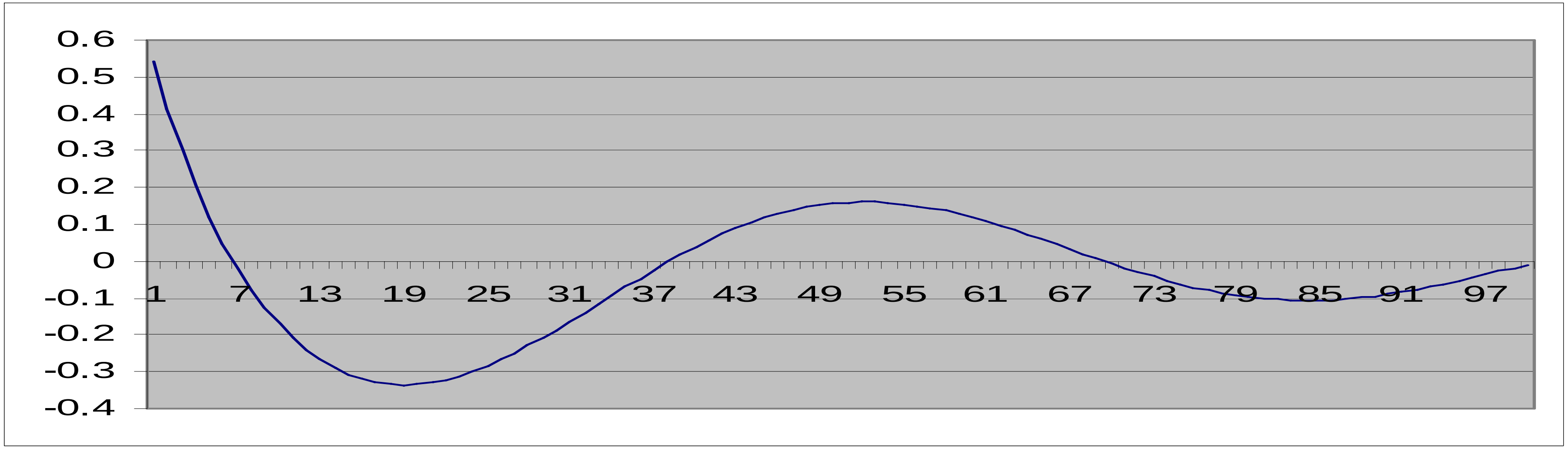




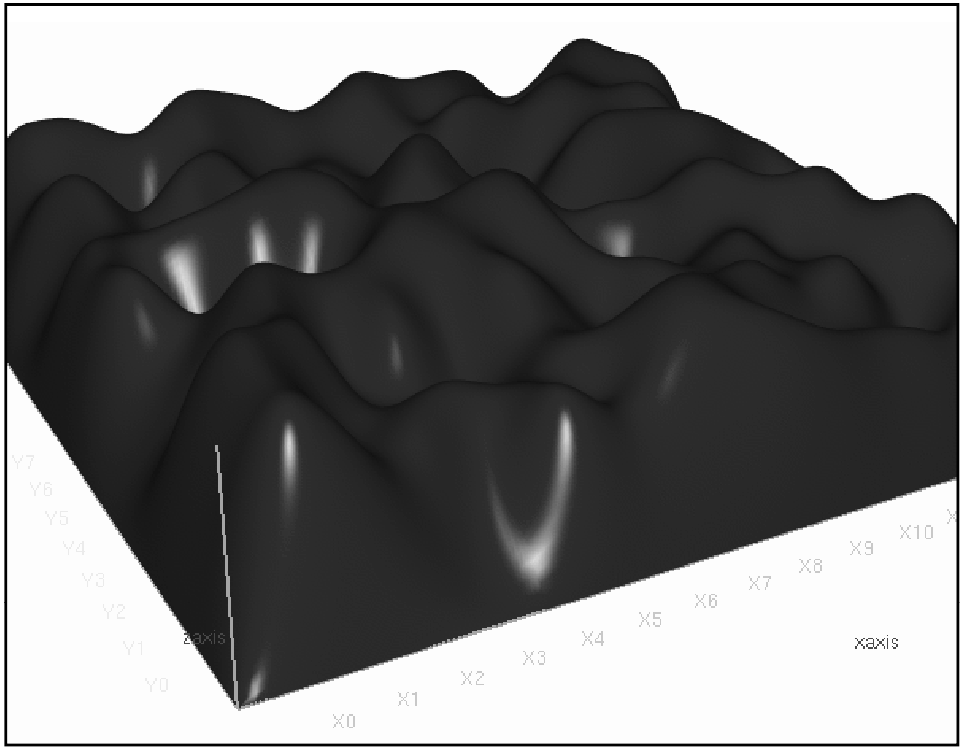
  - Pie charts

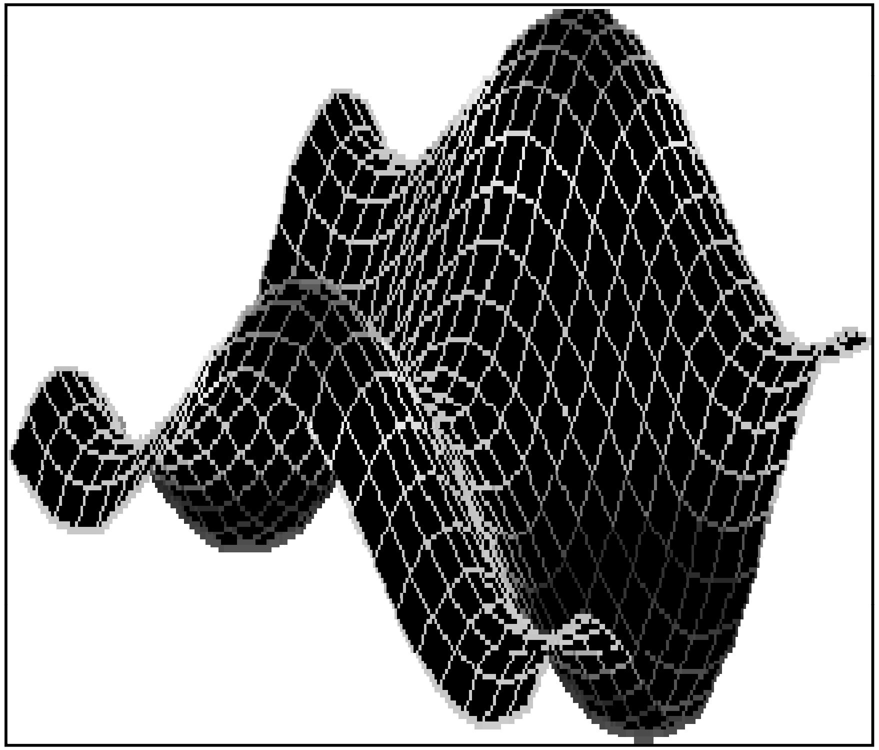


- Curves



- Surfaces

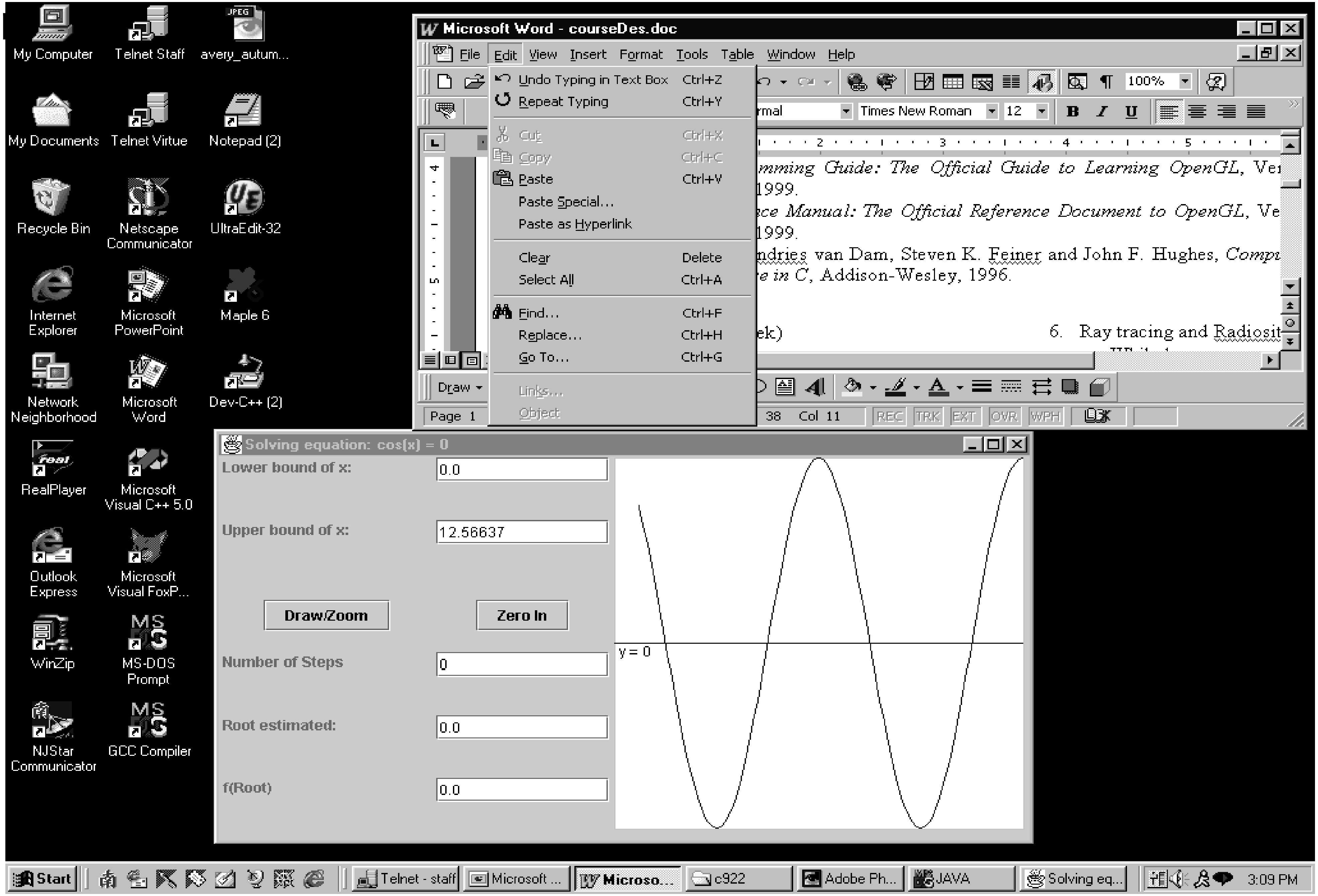




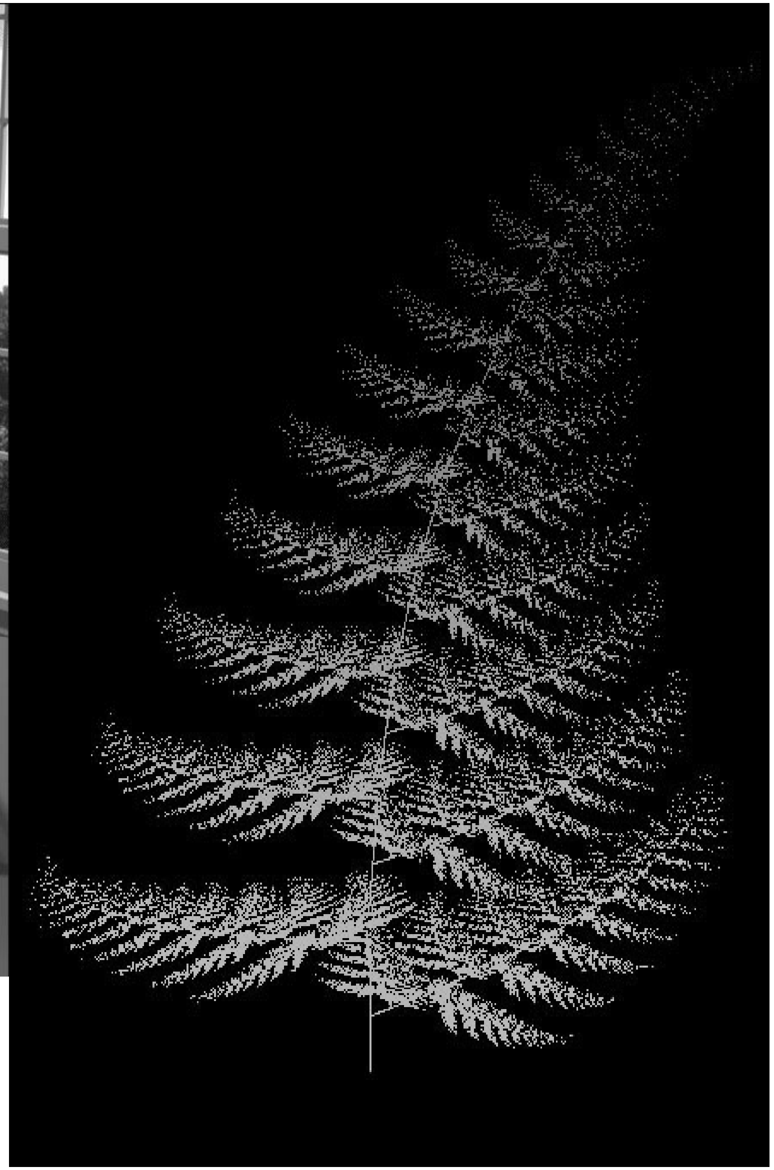
- Weather charts

- Graphical user interface

icons, frames, labels, fields, text-area, buttons, pop-up

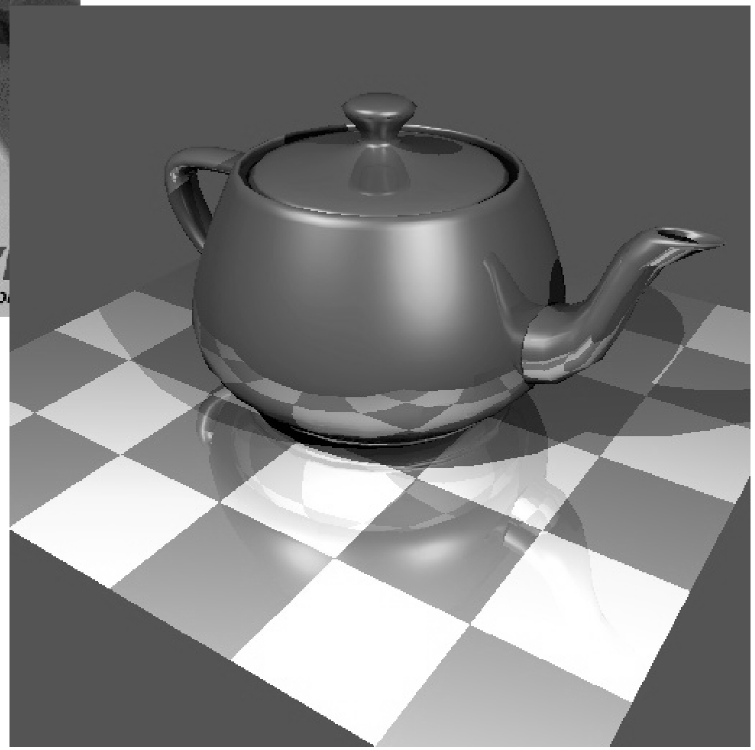


- Synthesizing images



- Virtual idol (Reiko Arisugawa)

➢ Ray tracing images

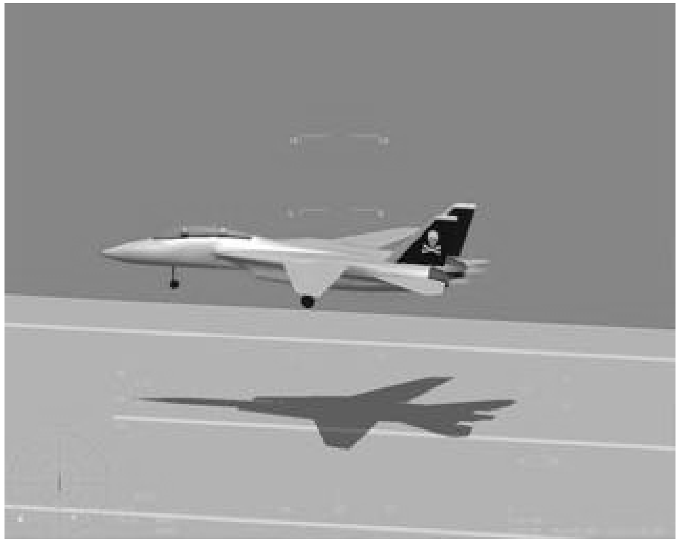



Dominique Rossi

- Animation
  - films

- Games

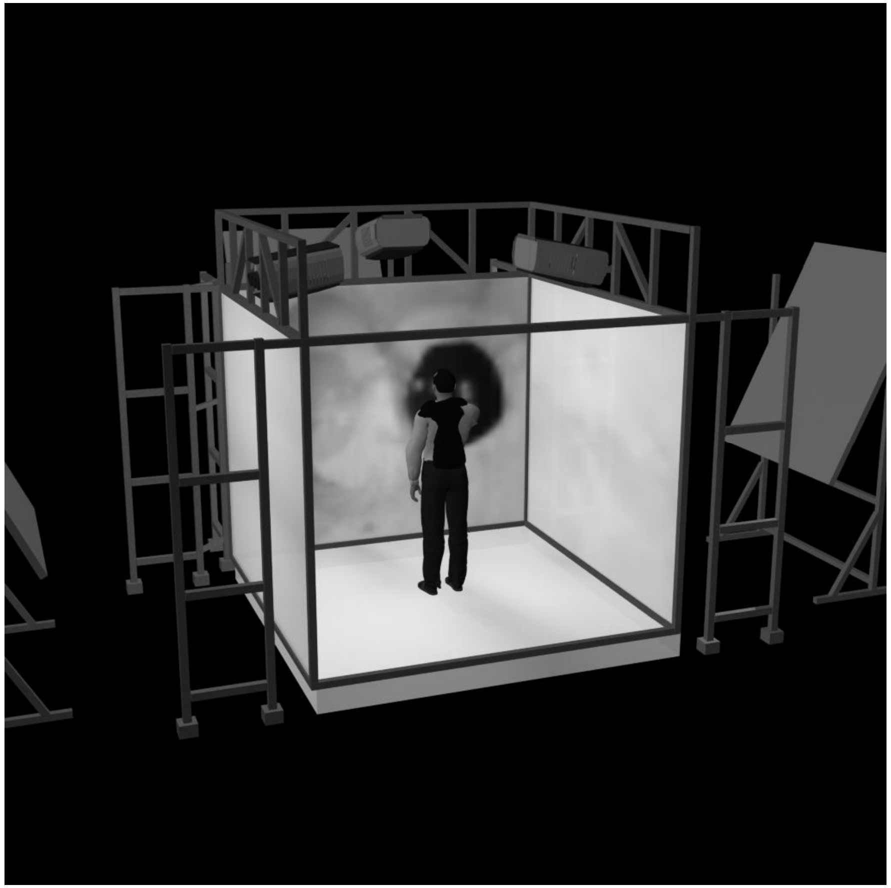
■ Flight simulators



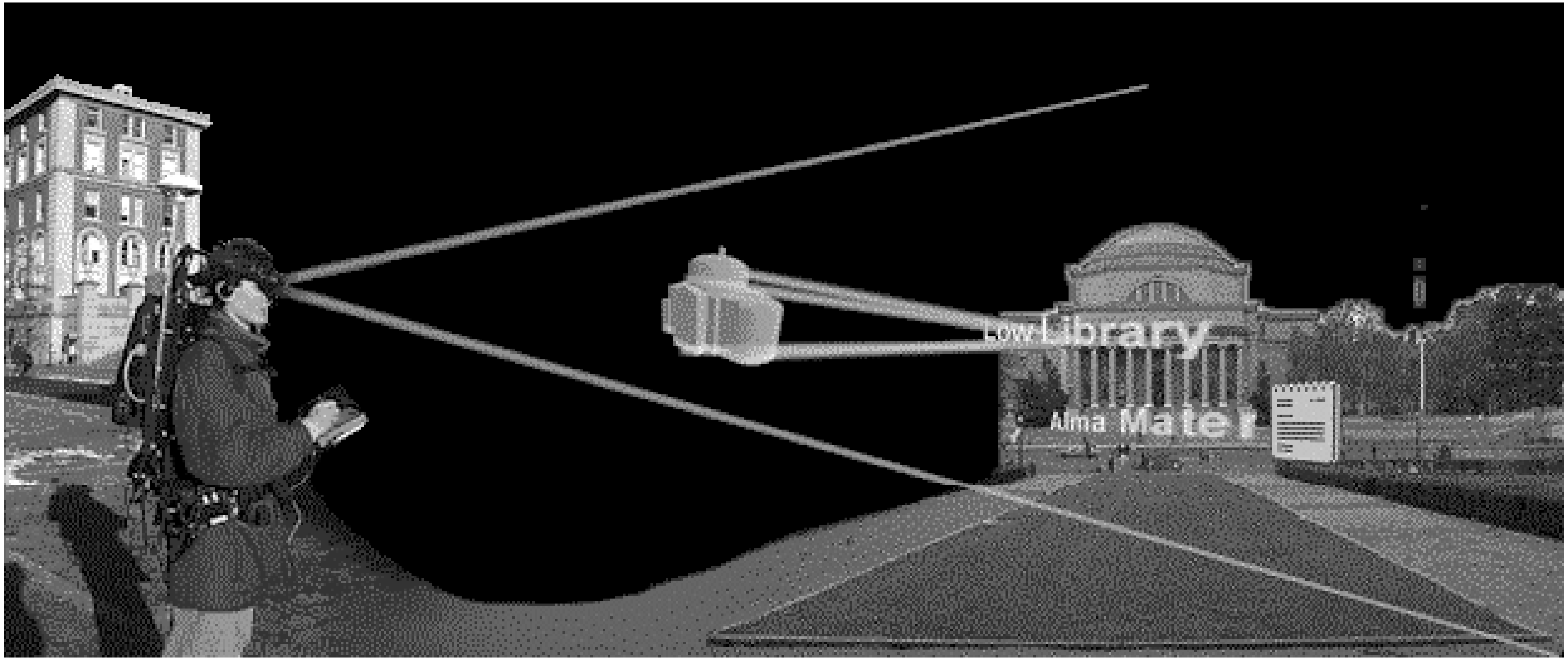
- Virtual reality

  provides true 3-d scenes and interactions

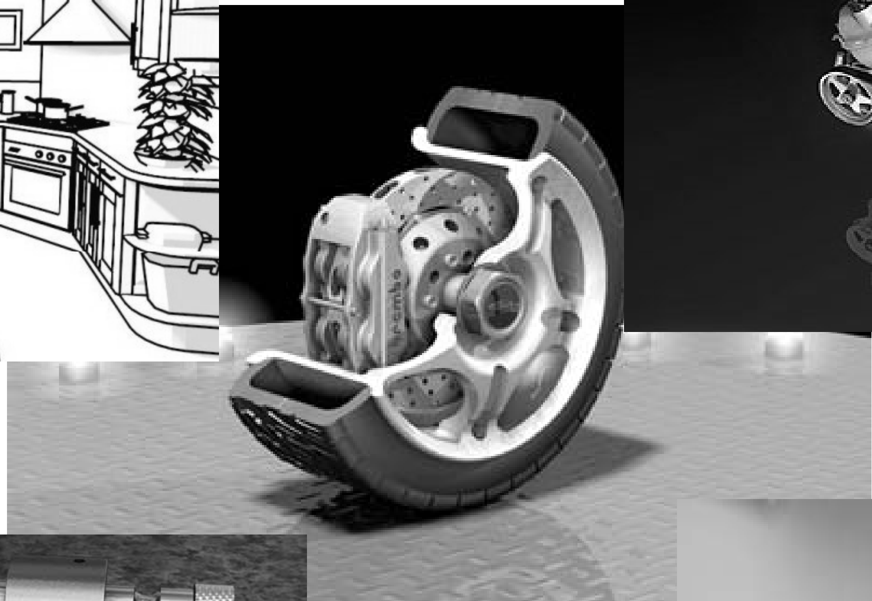
  - Head-mounted display (HMD)
  - A system for tracking the position of HMD
  - Data glove

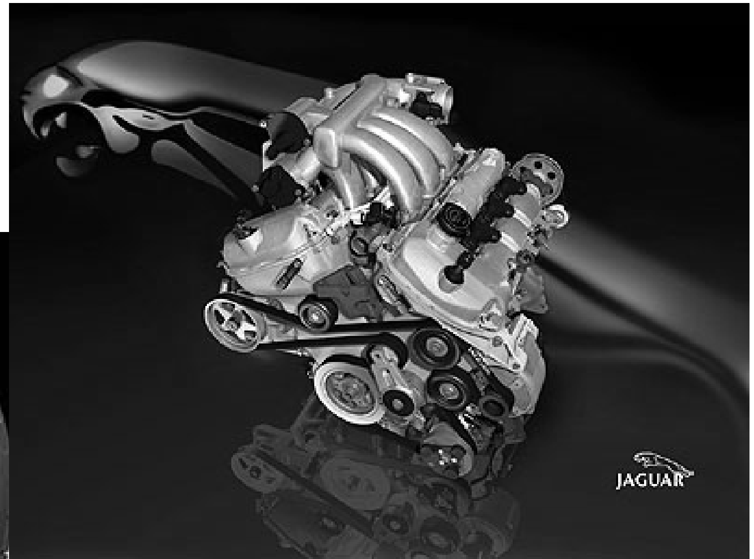


- Augmented reality
  - Video or optics superimposes computer-generated data on real world

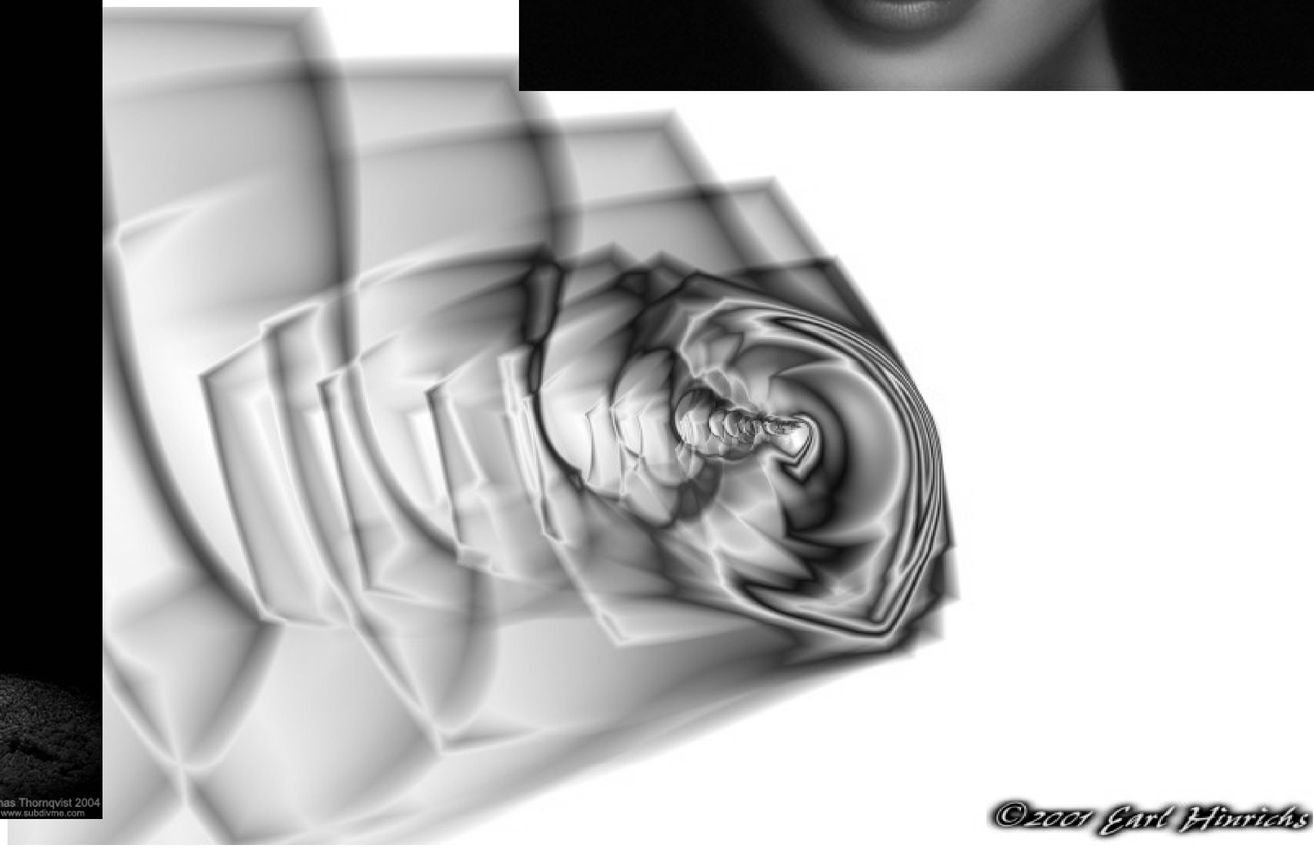


■ Industry (CAD)

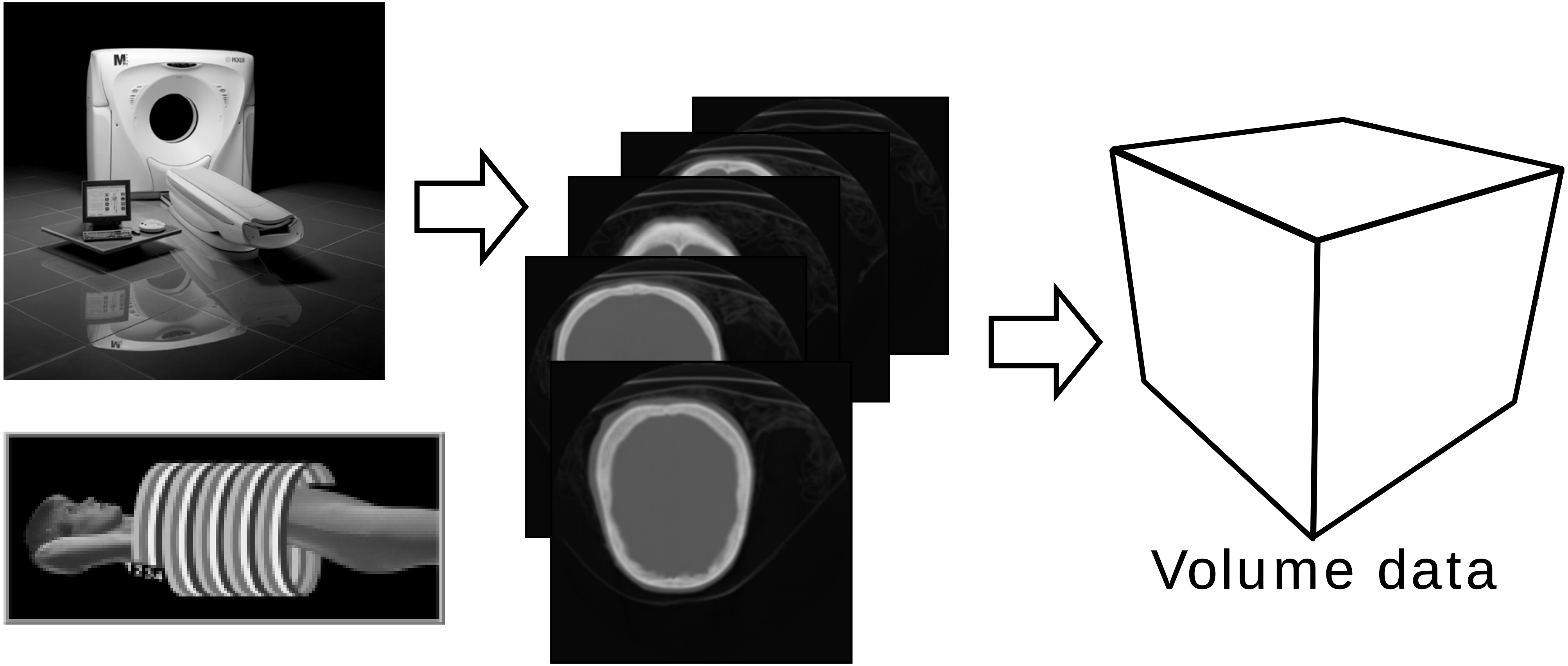




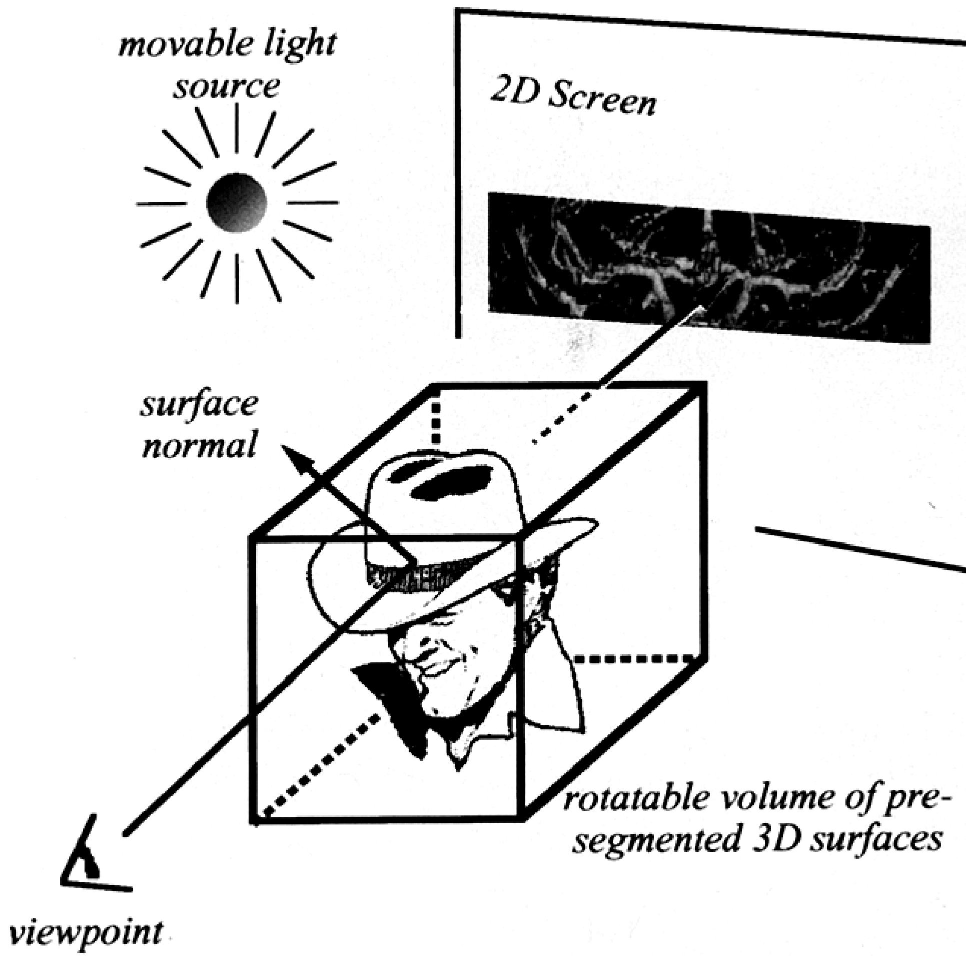
- Computer Art



■ Medical Application

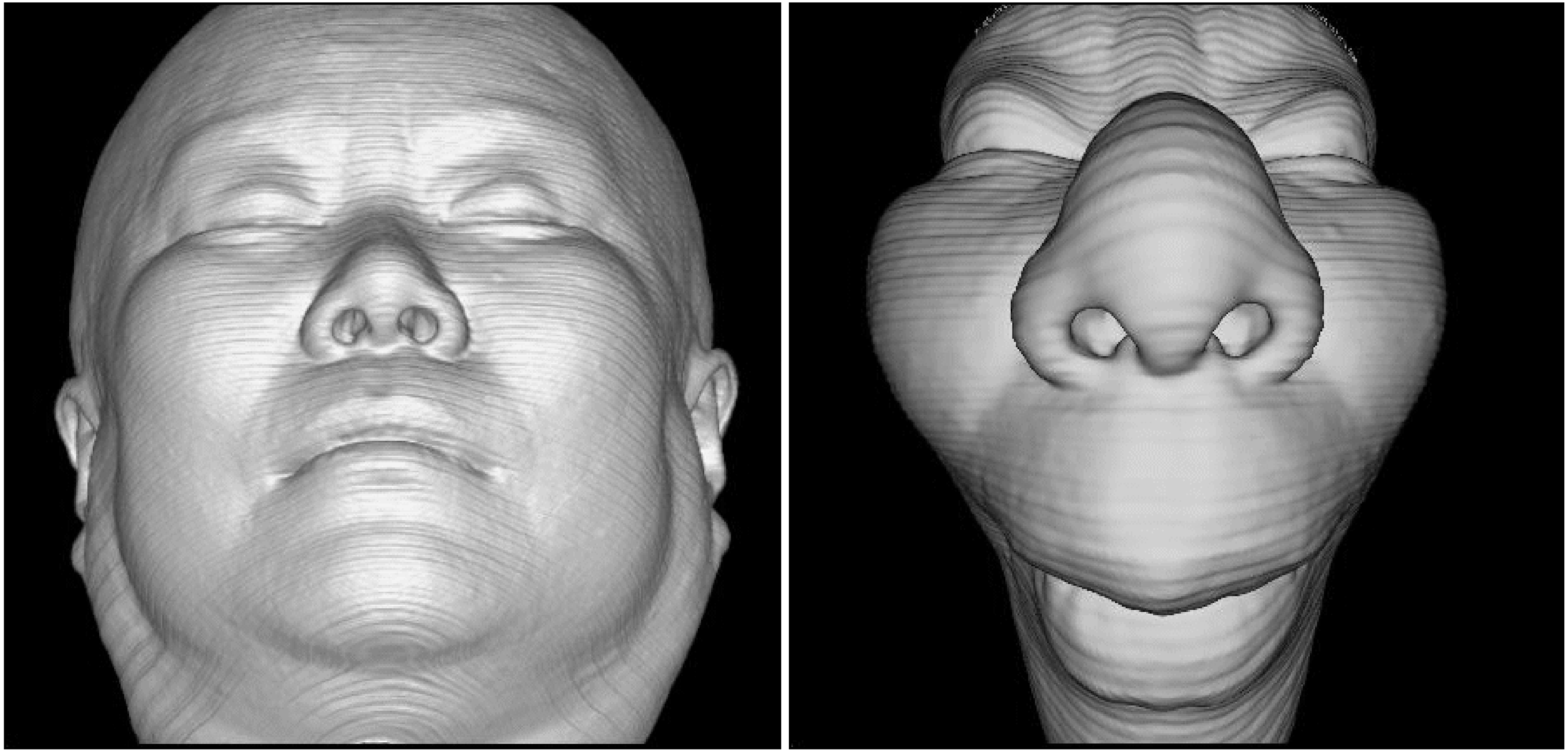


How we get an 2D image from the volume data (Ray casting based Volume Visualization)

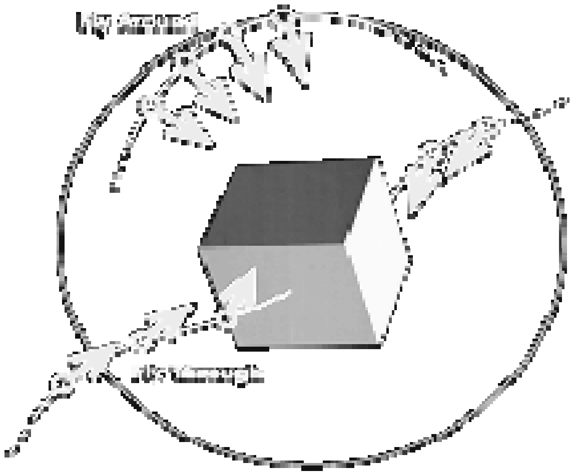


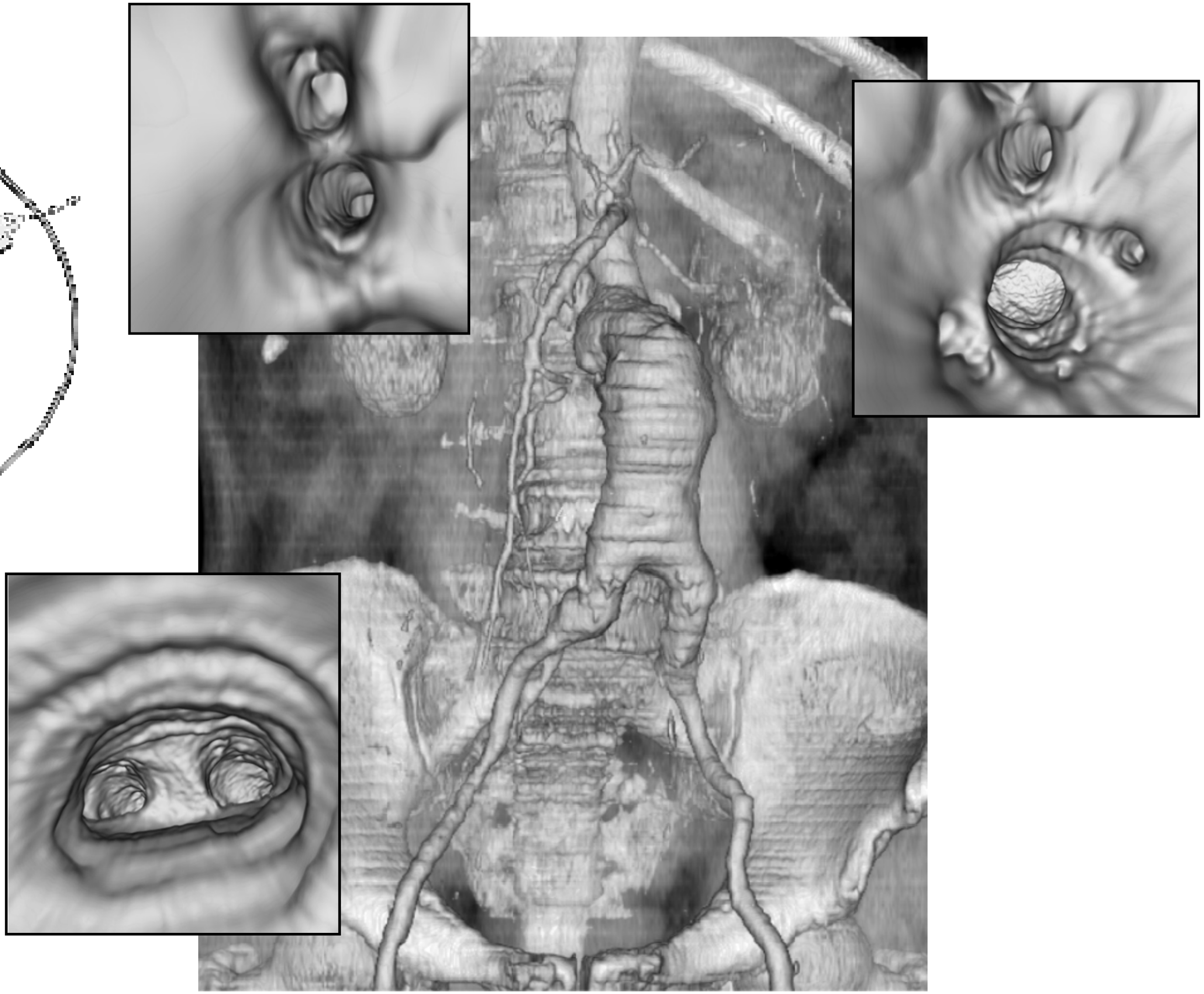
- Treat each pixel as a light source
- Emit light from the image to the object space
- Sampled values along the ray are accumulated

Nonperspective Perspective

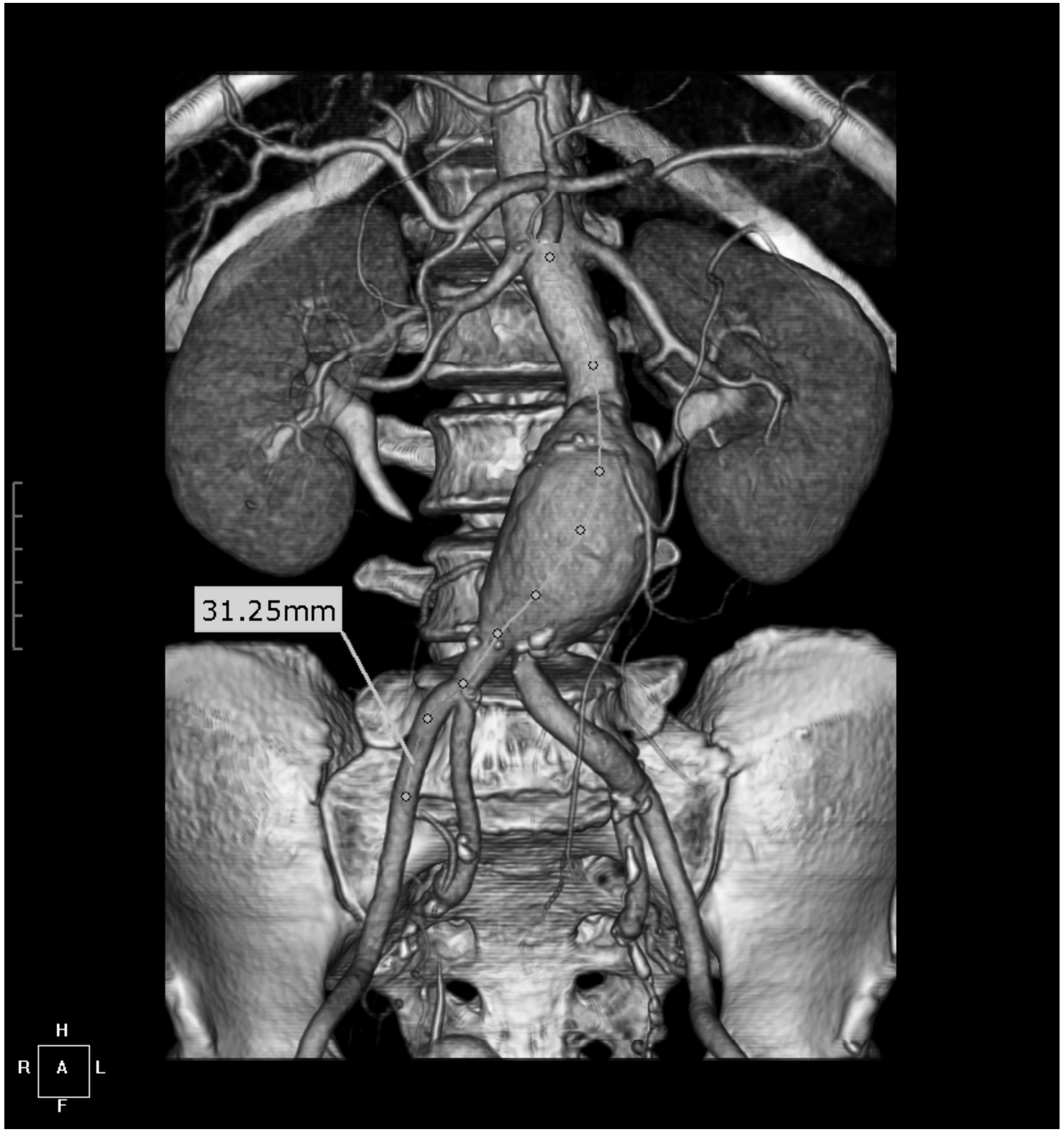


Virtual Angioscopy

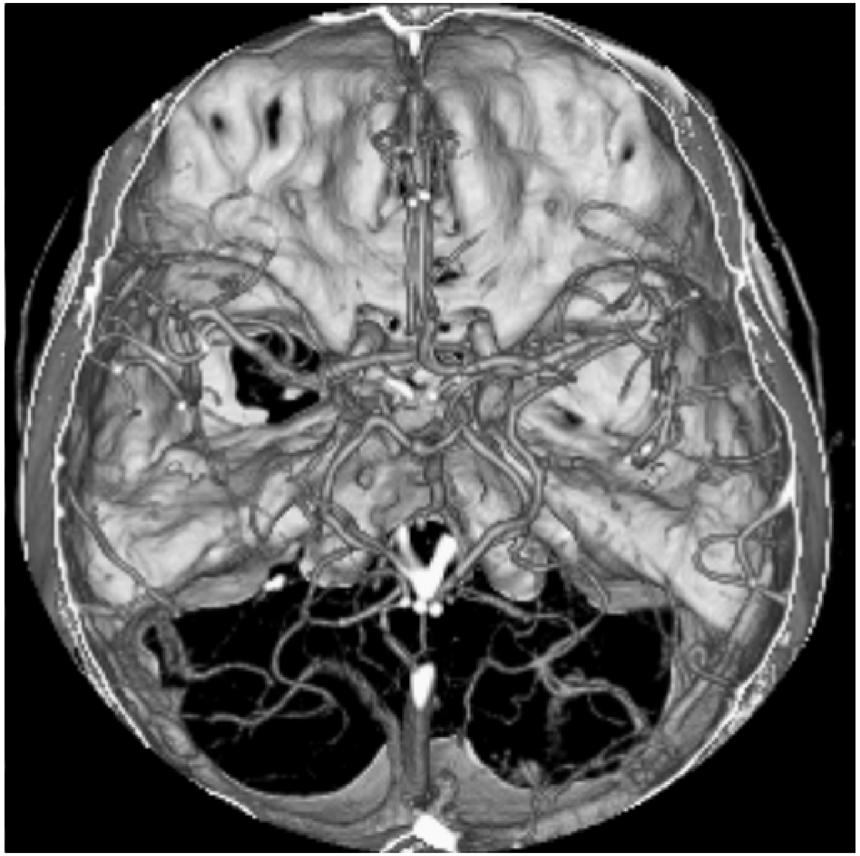




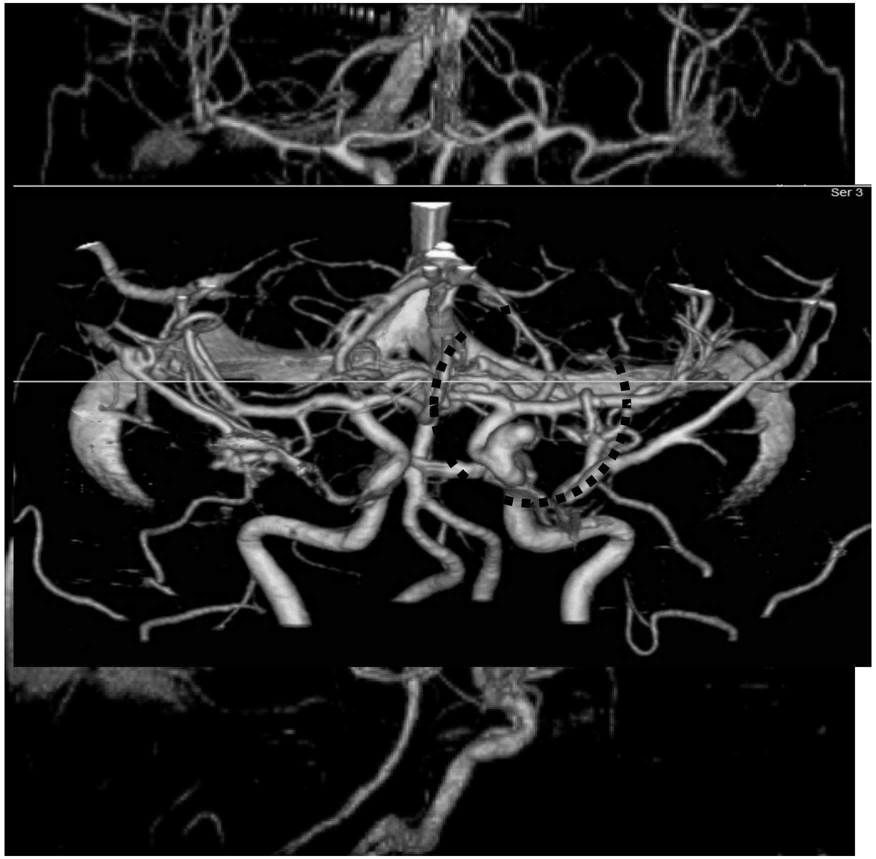
AAA, Stent-graft Design



Brain Subtraction

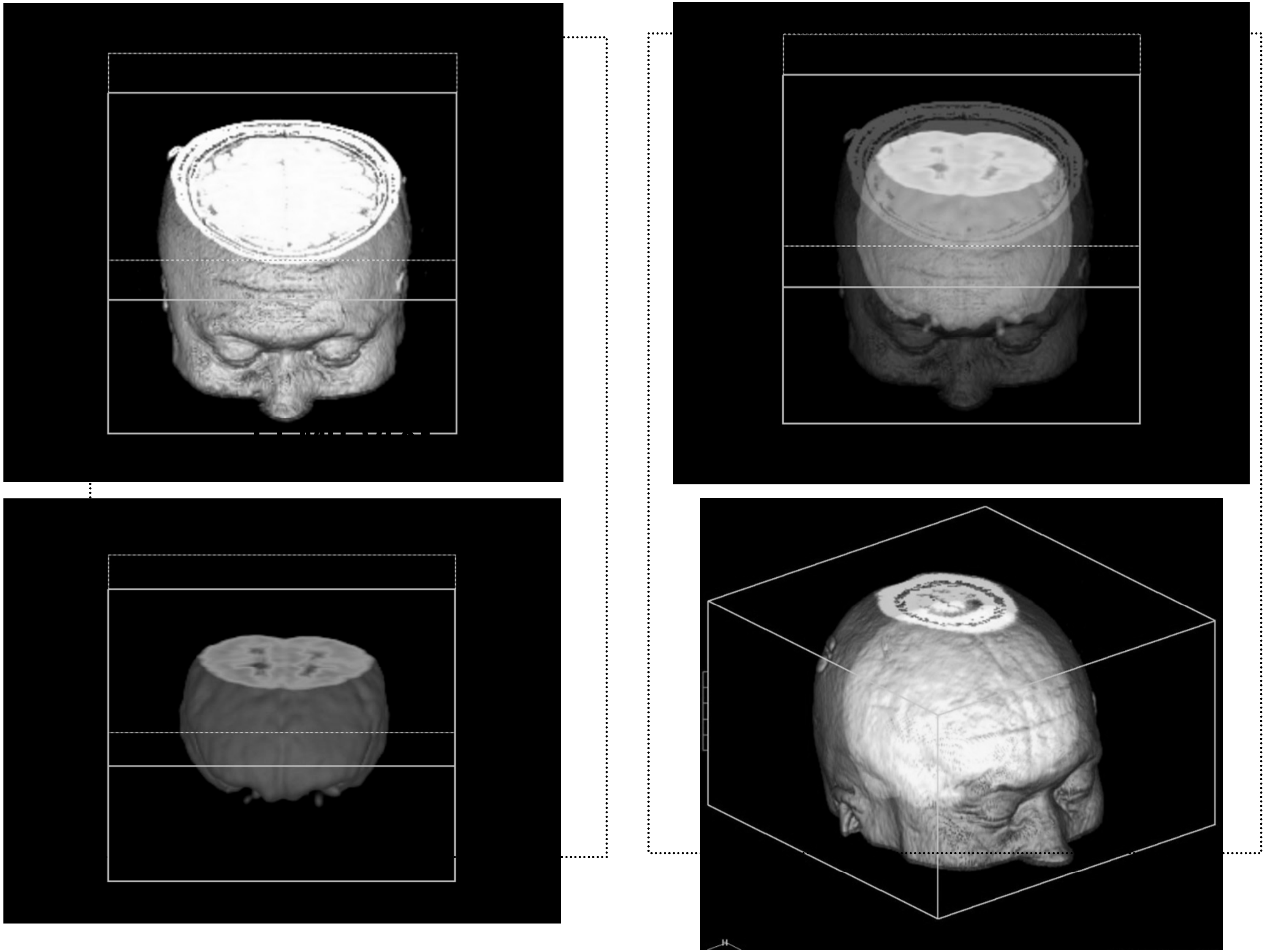


뇌 CT 혈관조영영상

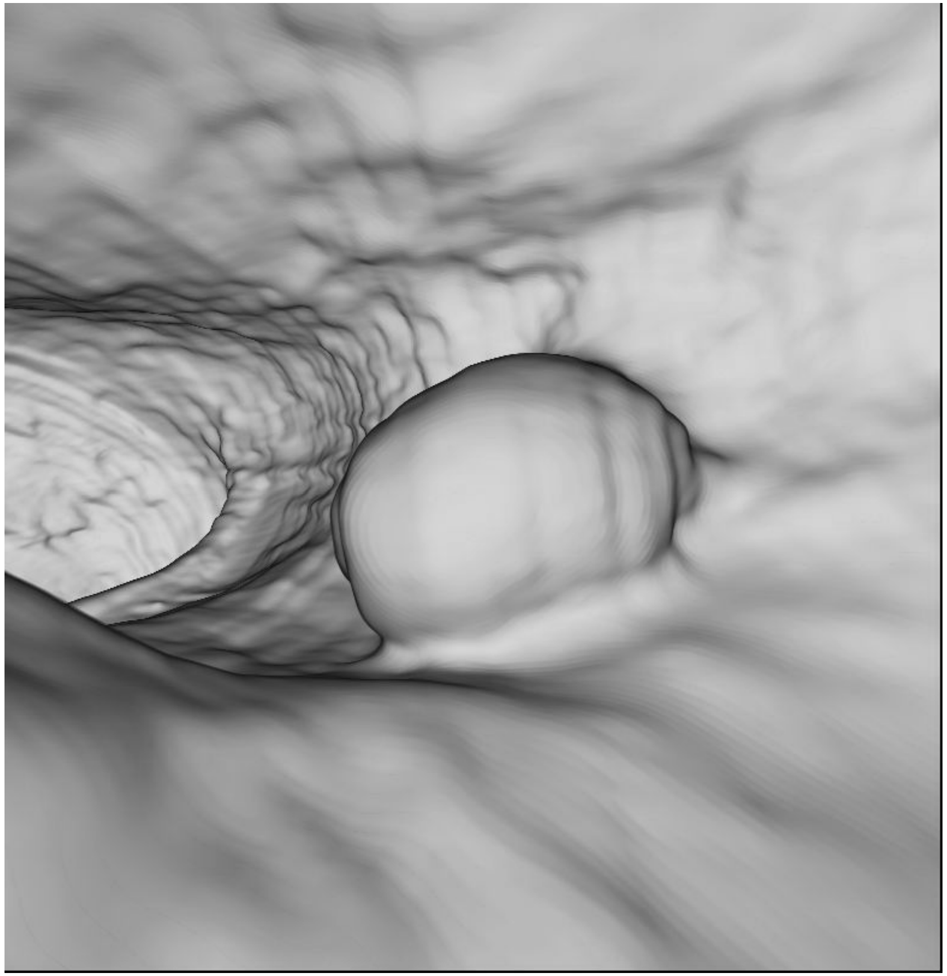


뇌 CT 영상
뇌혈관 추출 및 가시화

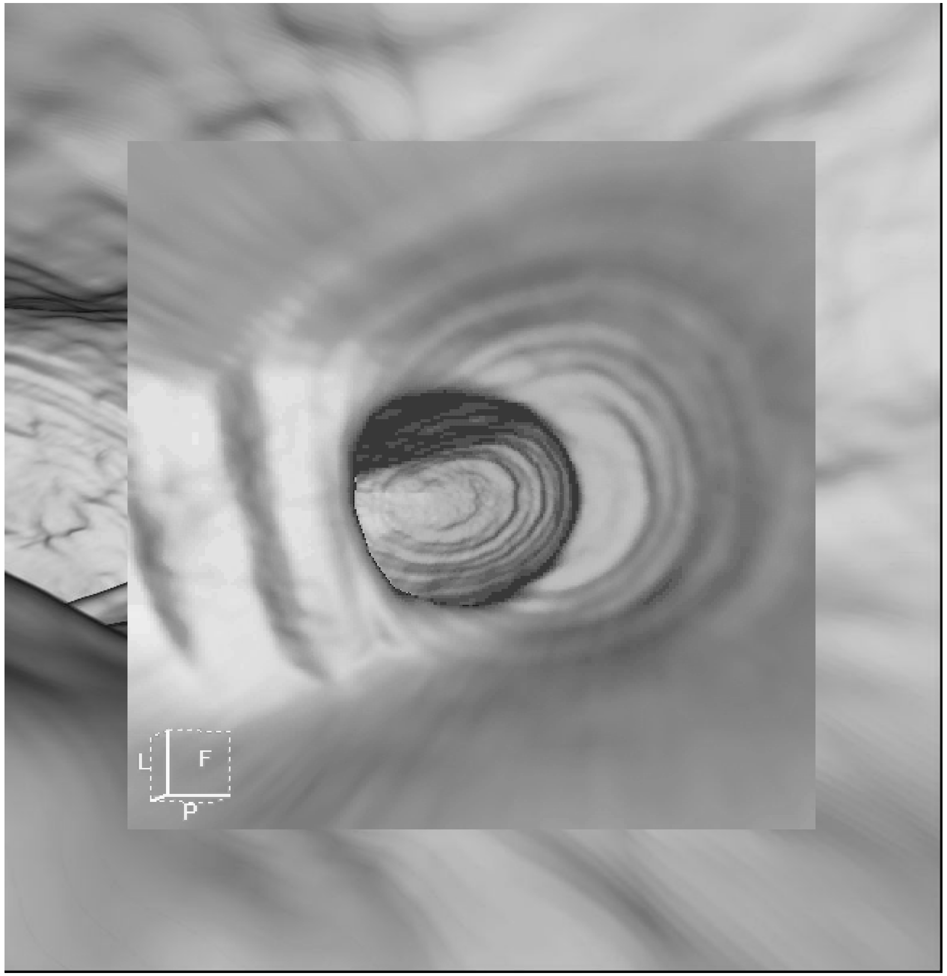
Registration of PET & MR images



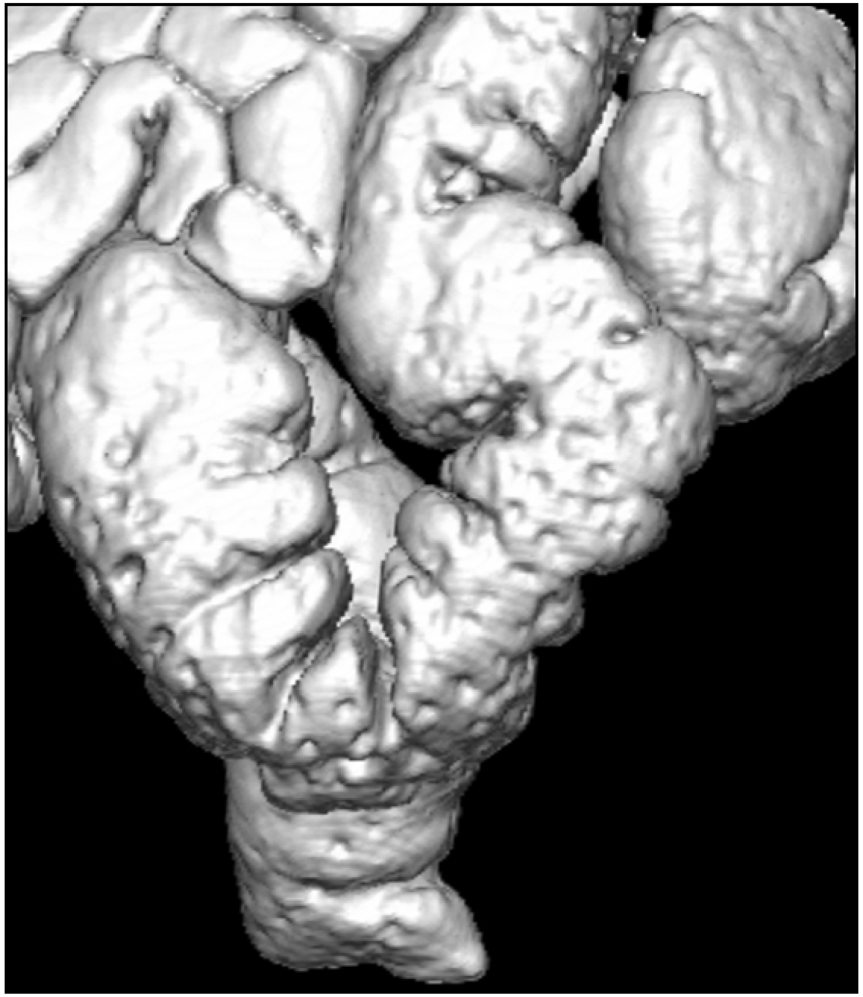
CT Gastroscopy

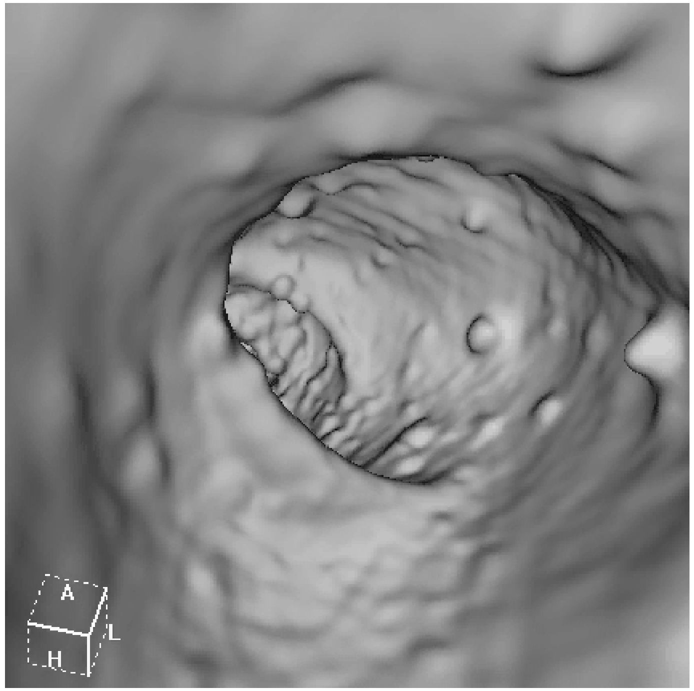


CT Gastroscopy



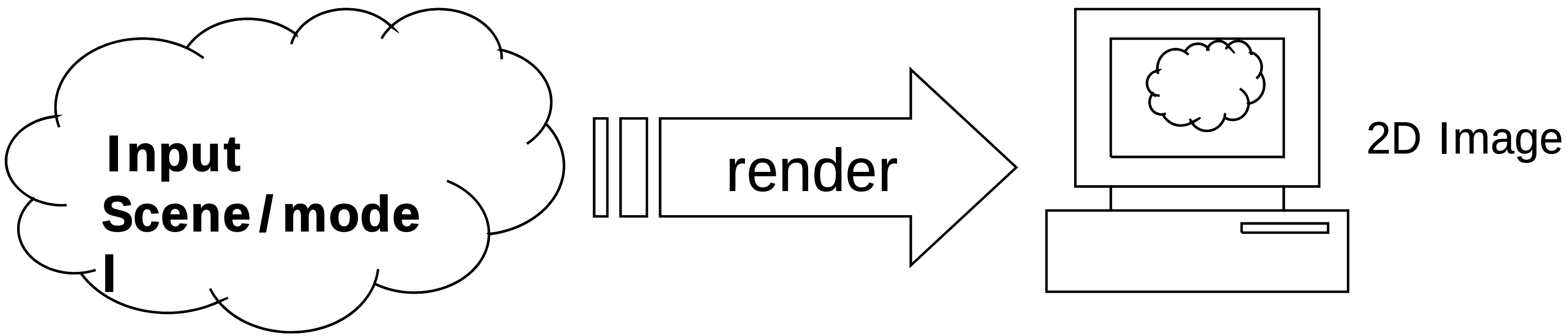
CT Colon





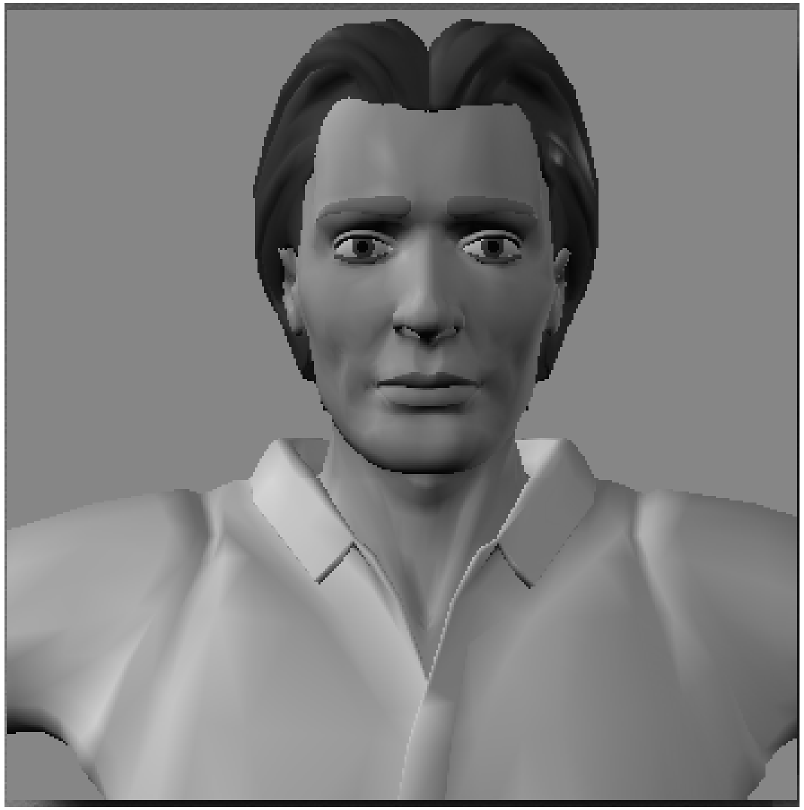
How we get Computer Image

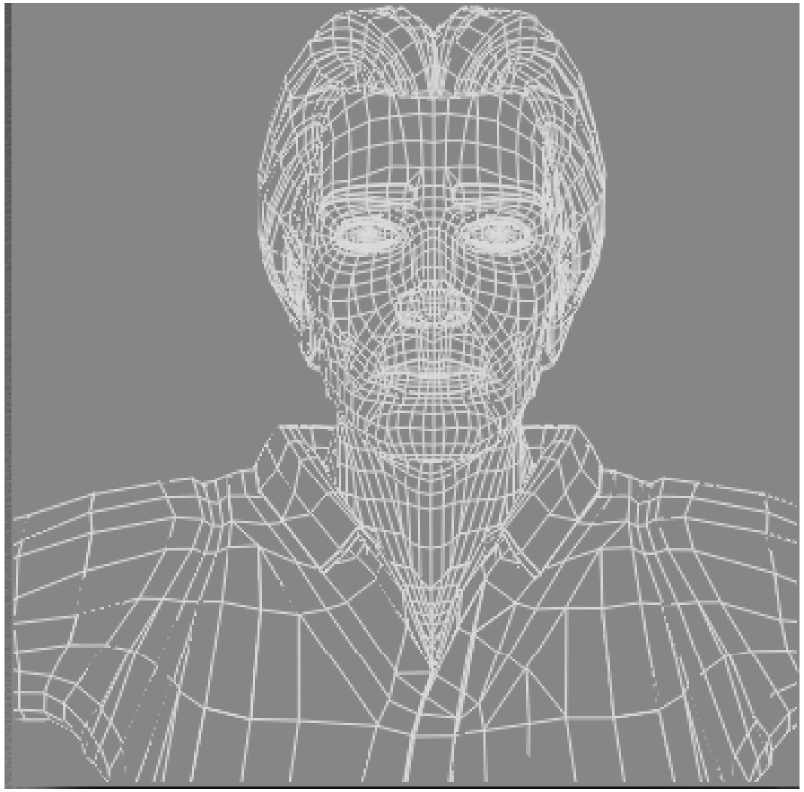
- Rendering is the conversion of a scene into an image



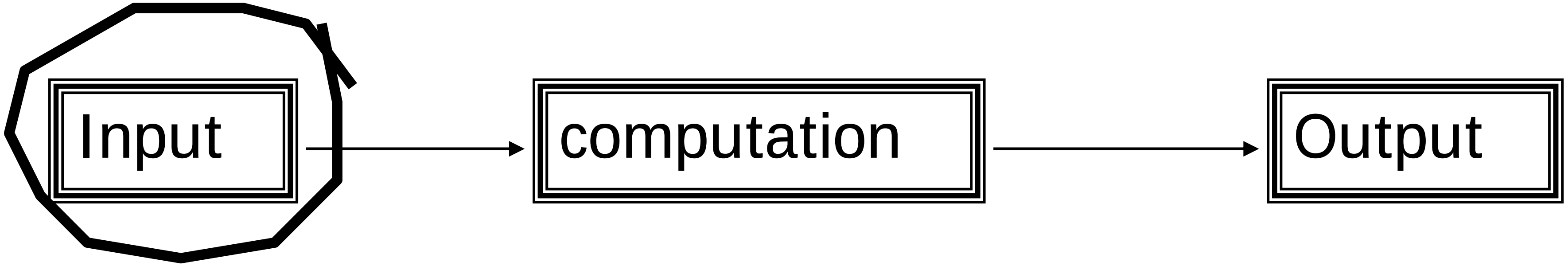
  - Scene is composed of a “model” of what we want to draw.
  - Models are composed of “primitives” supported by the rendering systems like Direct X or OpenGL.
  - Models entered by hand or created by a program

- Polygon Based Model
  - Any object can be broken down into polygons
  - Each polygon is represented by vertices
  - Vertex - a point in 2 or 3 dimensional space.

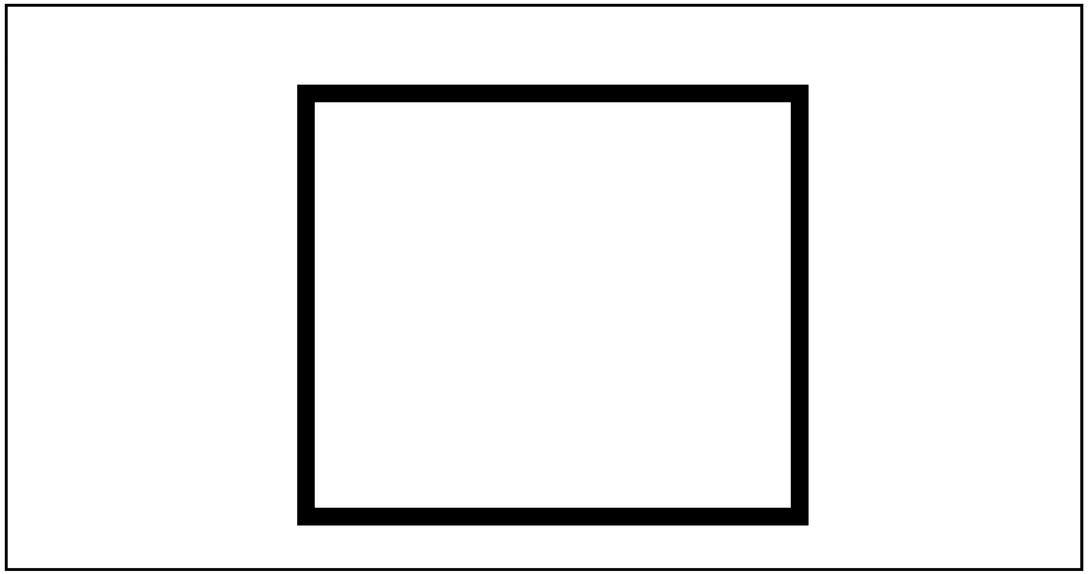




How we get Computer Image

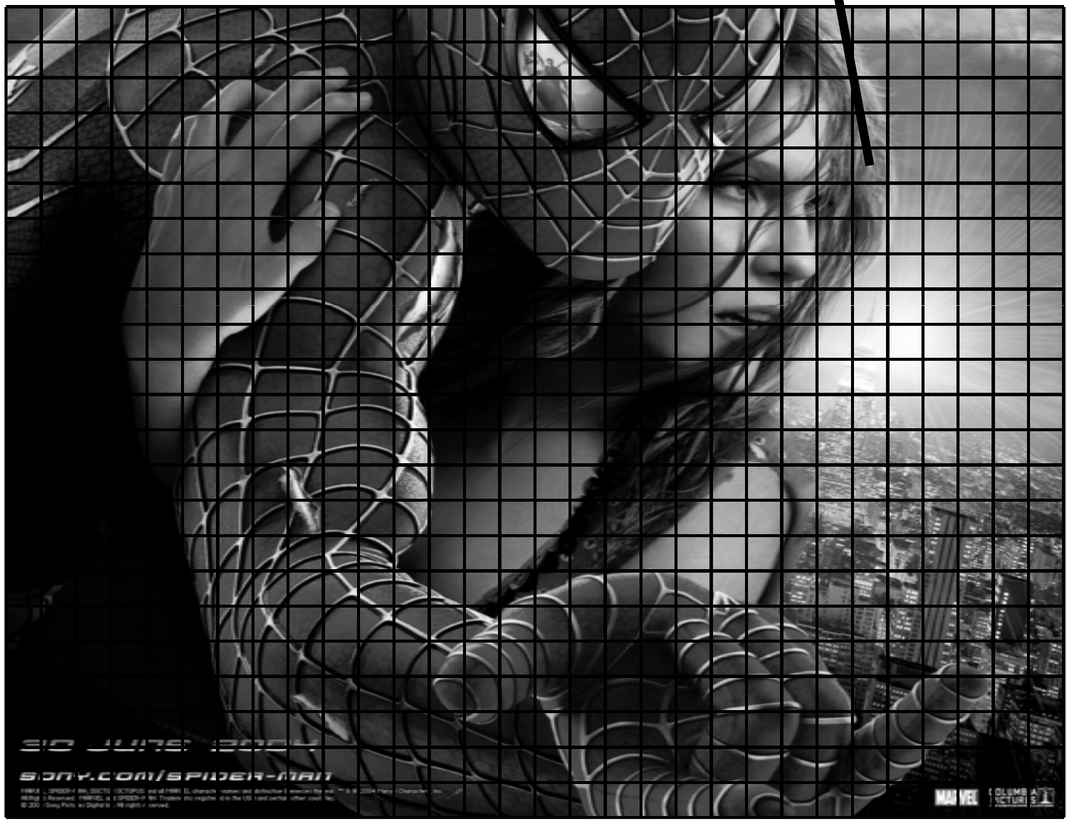


How we draw a rectangle in a image plane of a computer?



Pixel and resolution

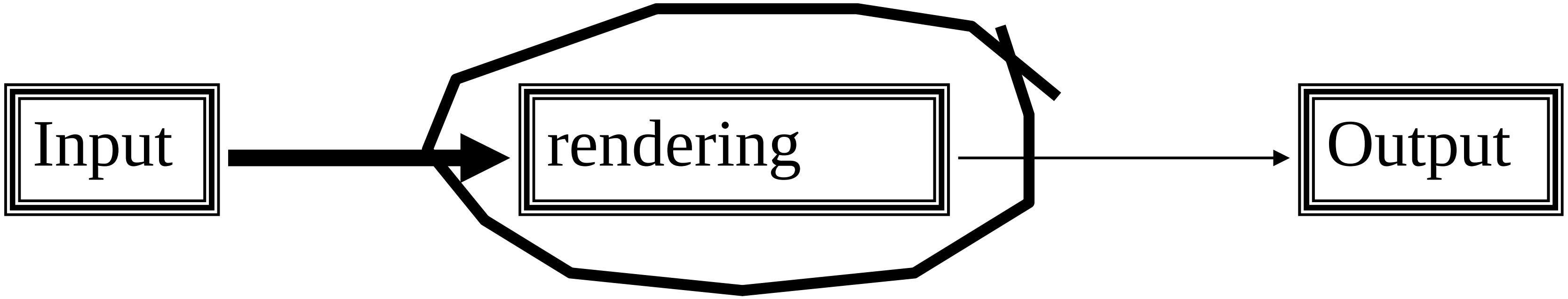
- An image = a set of Pixels (Picture element)



Dimensions of the screen

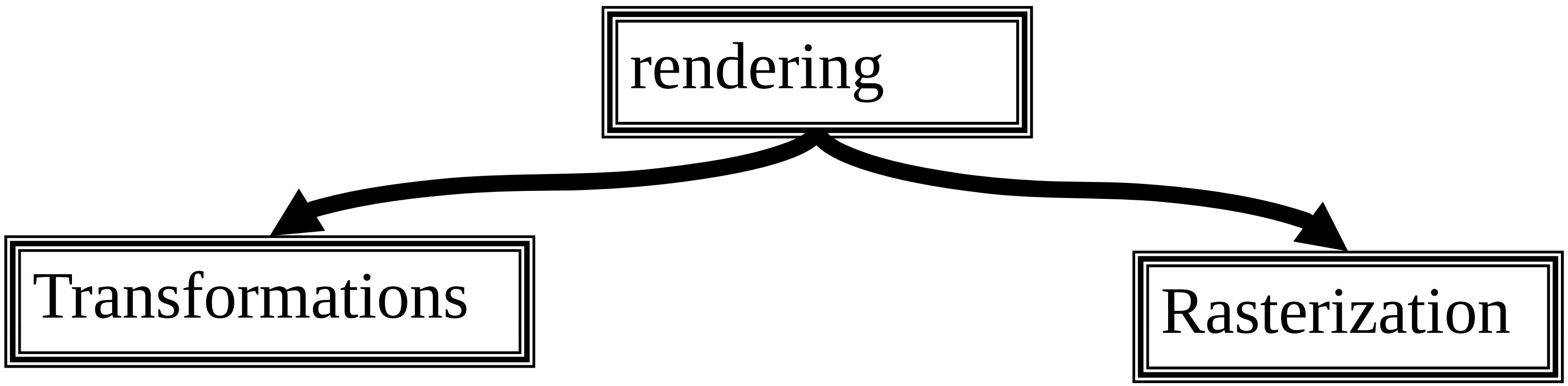
- SVGA(800 lines × 600 pixels)
- XVGA(1024×768)
- XVGA(1280×1024)

Computation Stage



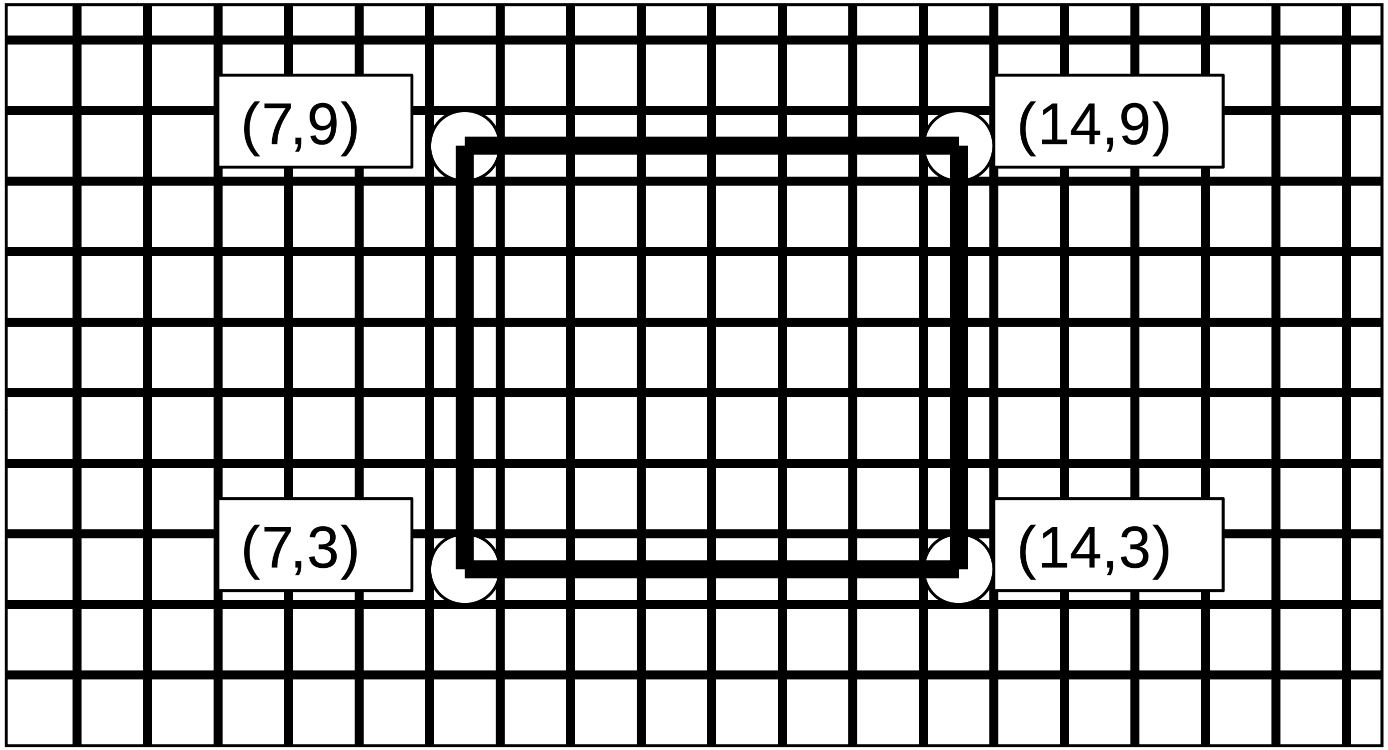
- Now that we have a ***model*** of what we want to draw, what goes on inside the computer to generate the output?

  ← we need to compute the location of each pixel and its color
- Generate (photorealistic) images from scenes (using lighting and shading)

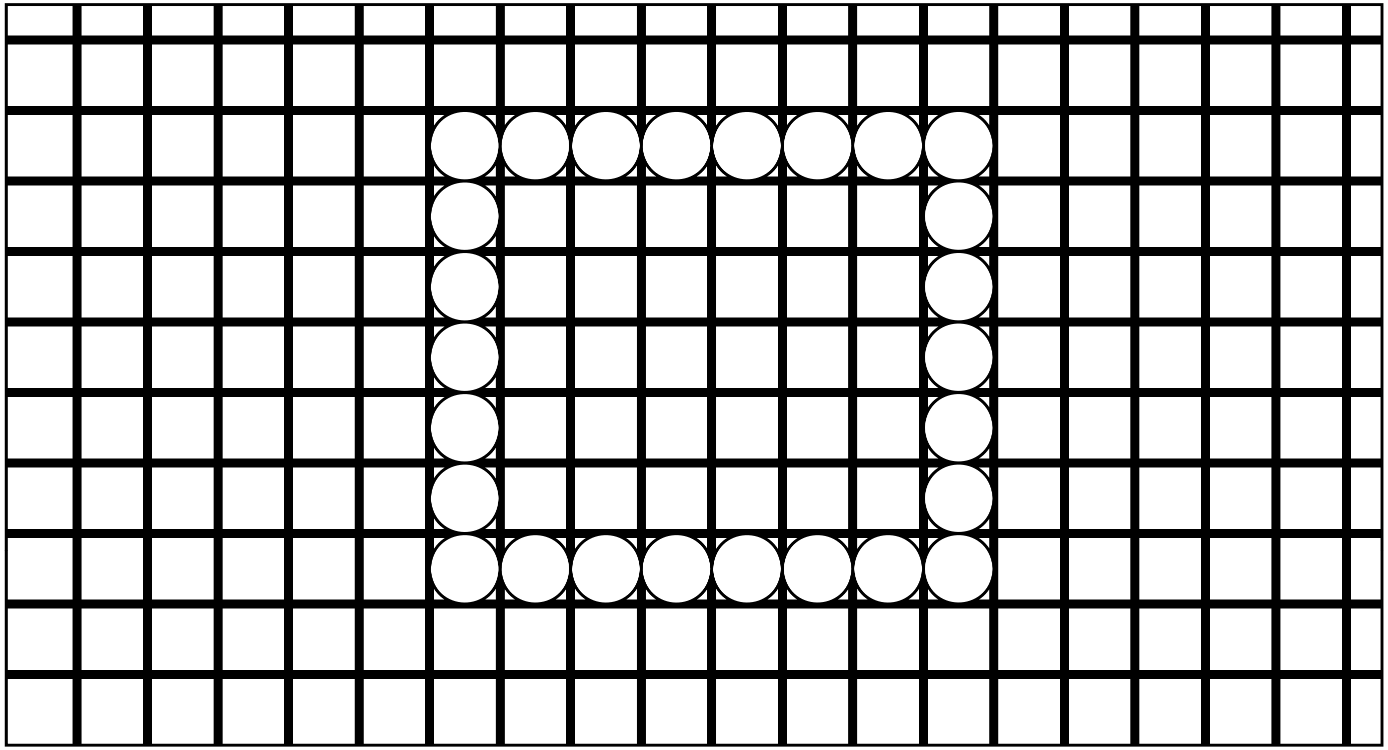


Partition the space

1. Define a set of points (vertices) in 2D space.
2. Given a set of vertices, draw lines between consecutive vertices.

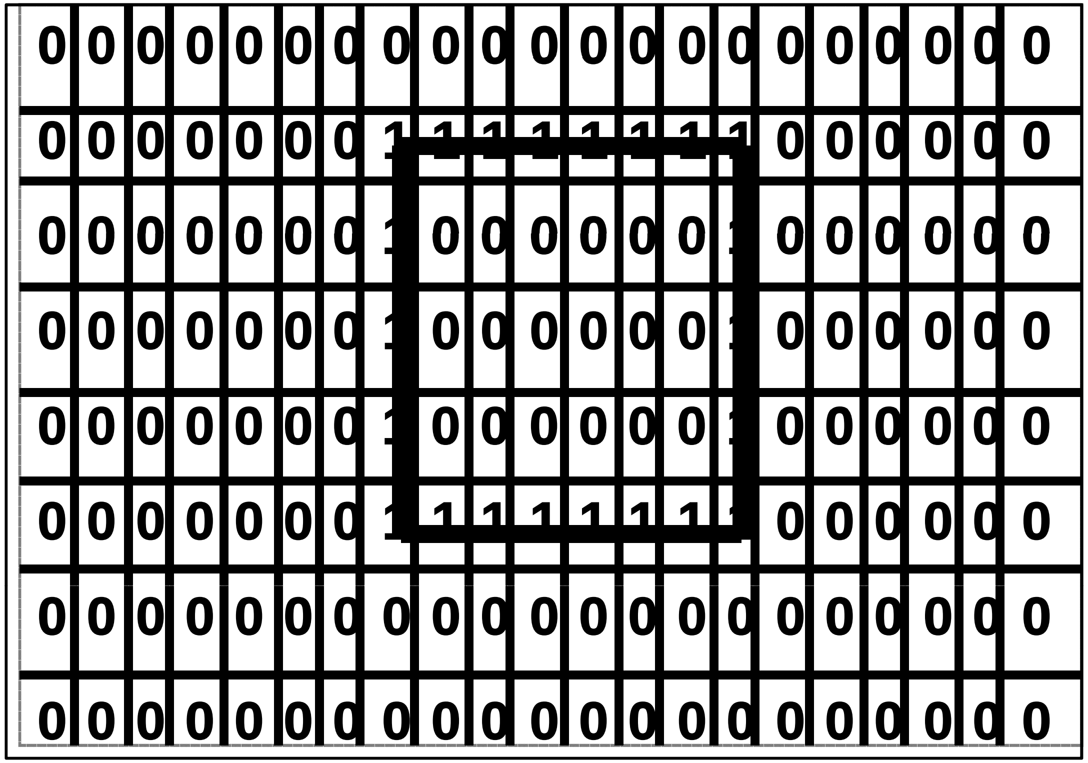


Find corresponding pixels



- Decide pixels on which each line locates

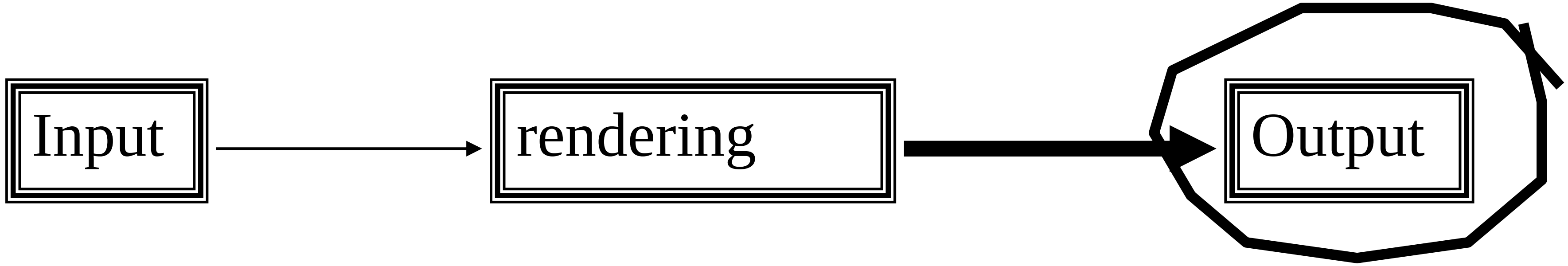
Save the results of pixel values



Frame buffer

- Frame buffer
  - a kind of memory with screen size
  - Locates on graphics card
  - Each pixel contains the color and/or transparency

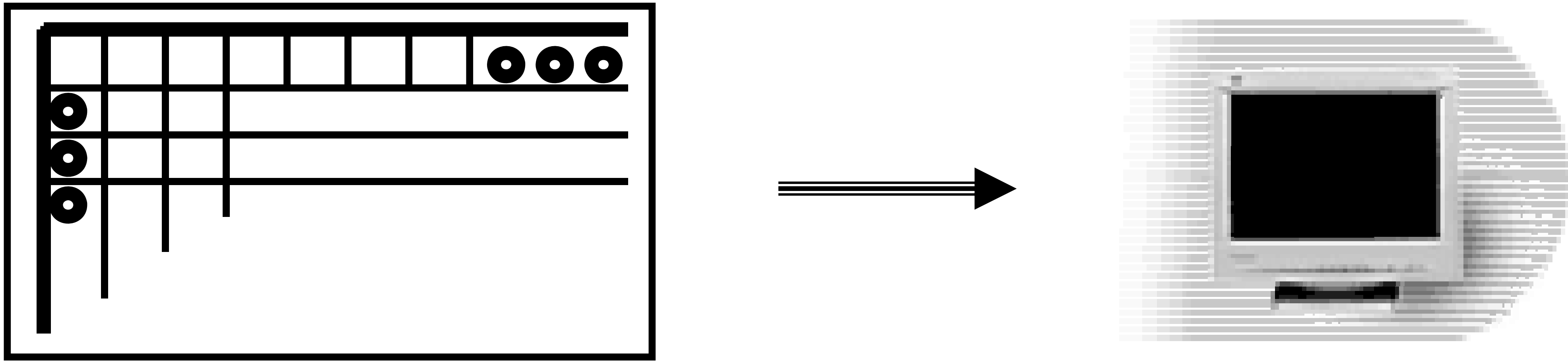
Output



We have an image (frame buffer or model), now we want to show it.

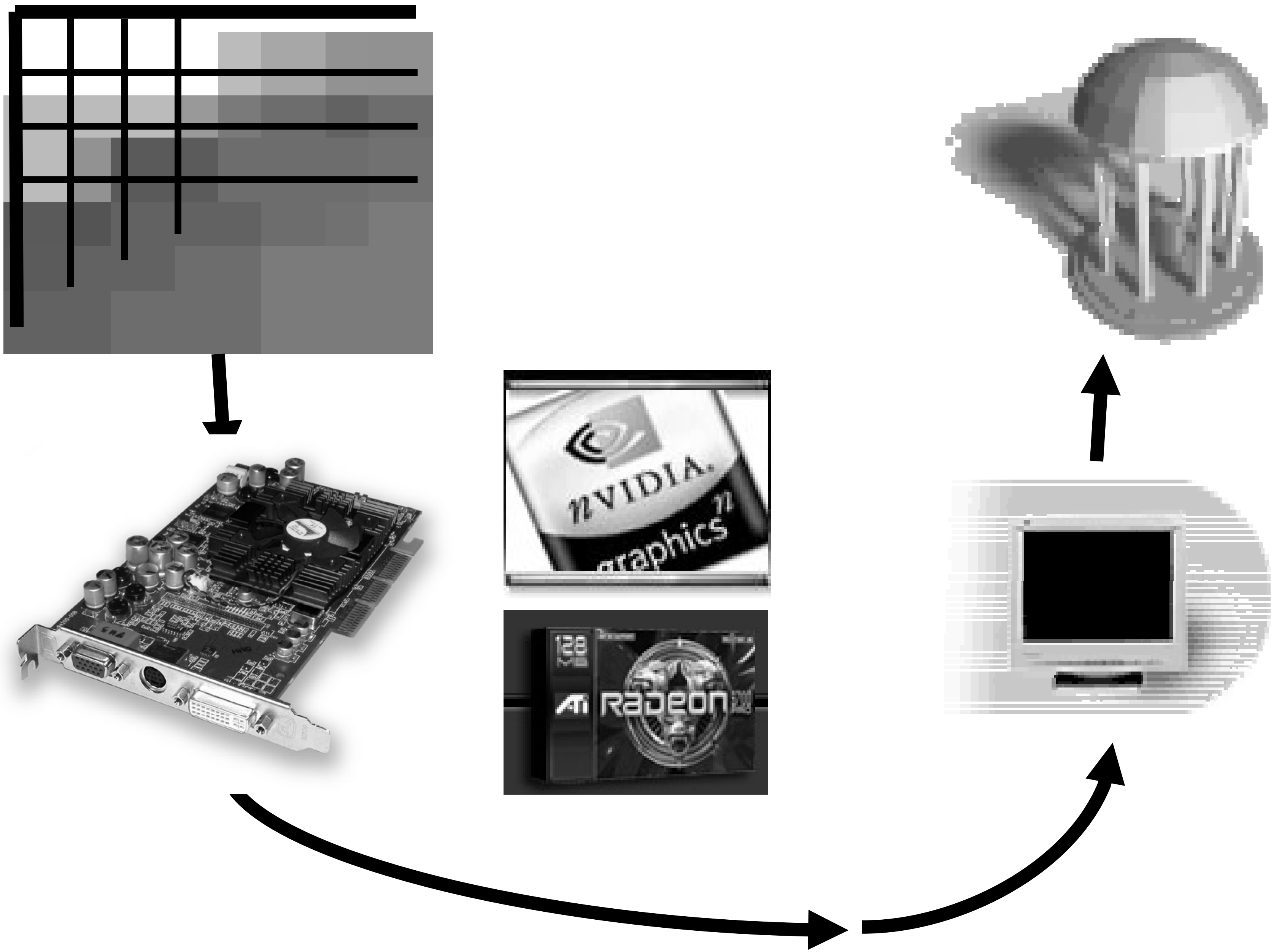
- Hardcopy (print)
- Display
  - Vector
  - Raster Scan

Frame buffer ➔ Monitor



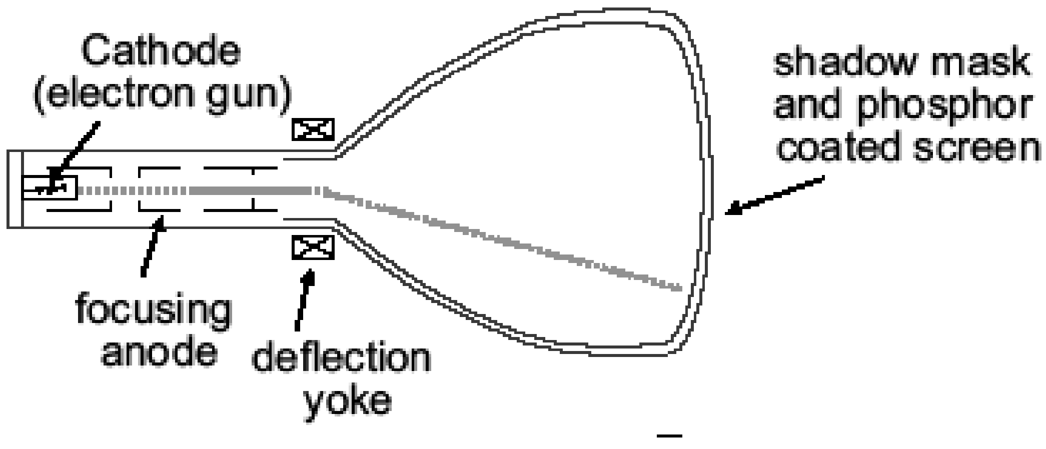
- The values in the frame buffer are converted from a digital (1s and 0s representation, the bits) to an analog signal that goes out to the monitor.
- A graphics card performs this operation, once per frame. This is done automatically (not controlled by your code), and the conversion can be done while writing to the frame buffer.

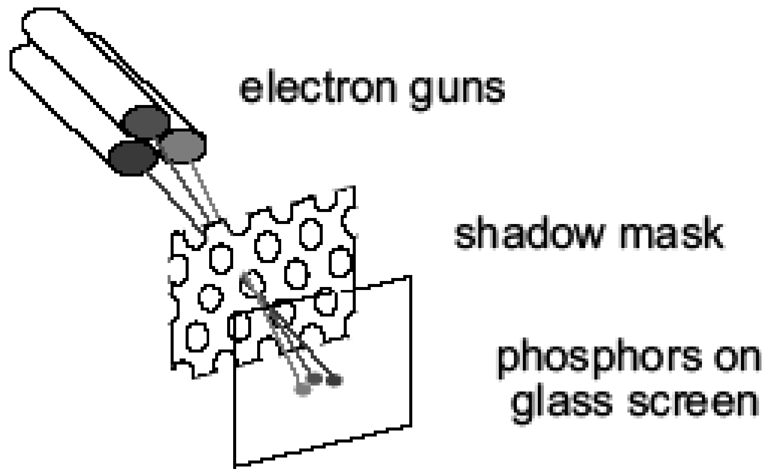
Frame buffer ➔ Monitor



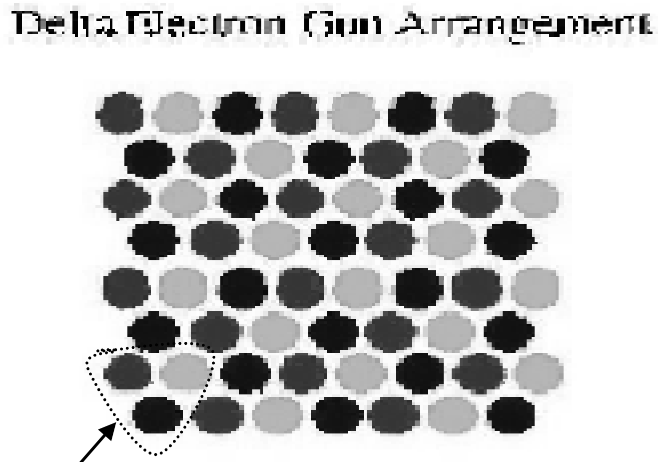
Display Monitor

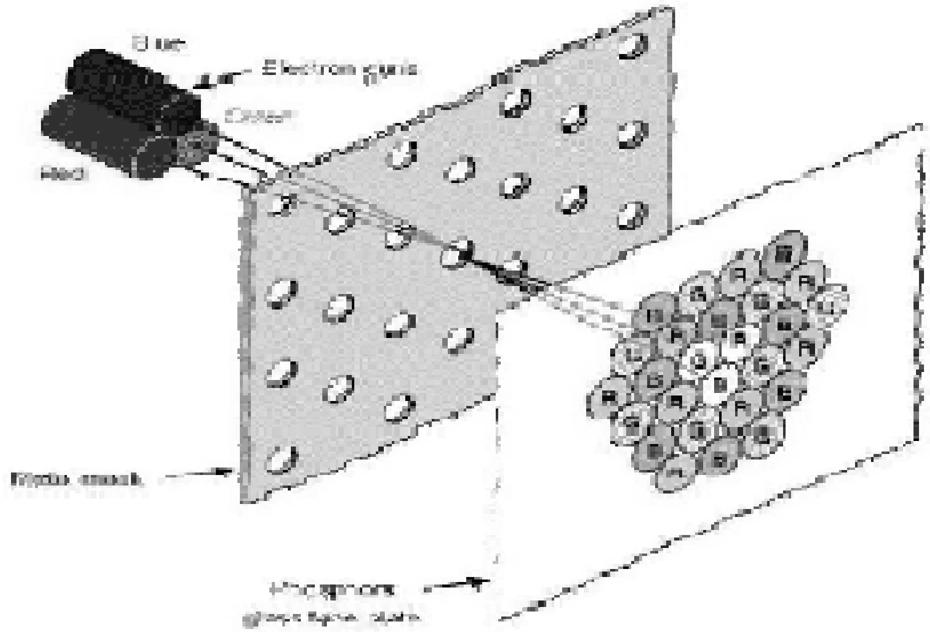
- Raster Cathode Ray Tube(CRT) is the most common display device
  - High resolution
  - Good color fidelity
  - High Contrast (100:1)
  - High update rates



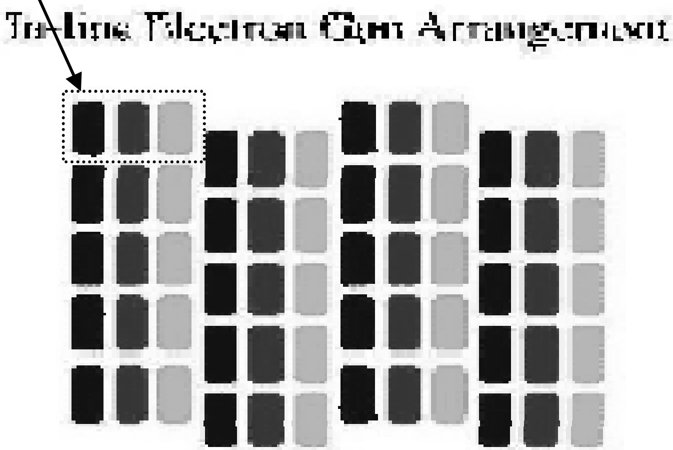


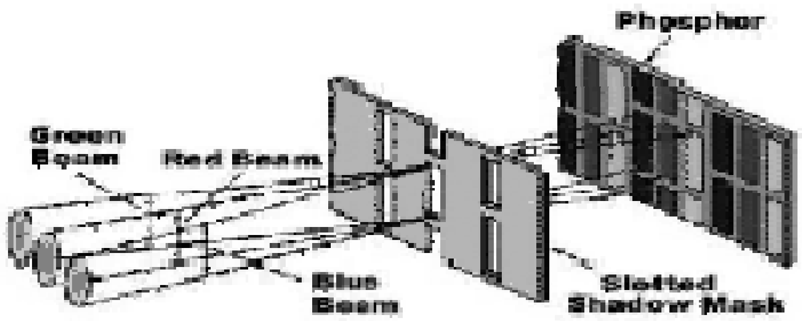
- Color CRT (3 guns: Red, Green and Blue)



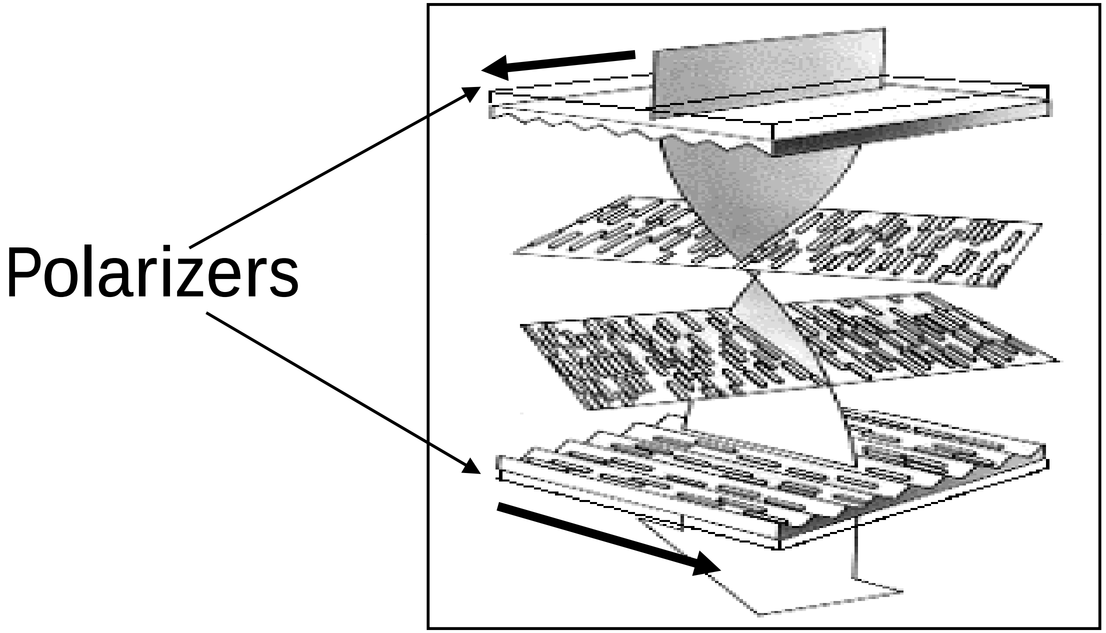


1 pixel

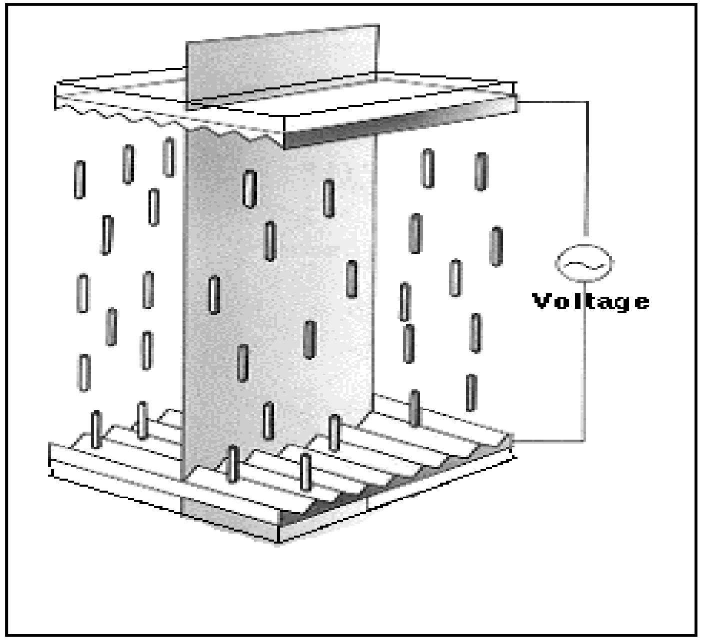




- Liquid Crystal Display(LCD) becomes more popular
  - Flat panels
  - Flicker free
  - Decreased viewing angle

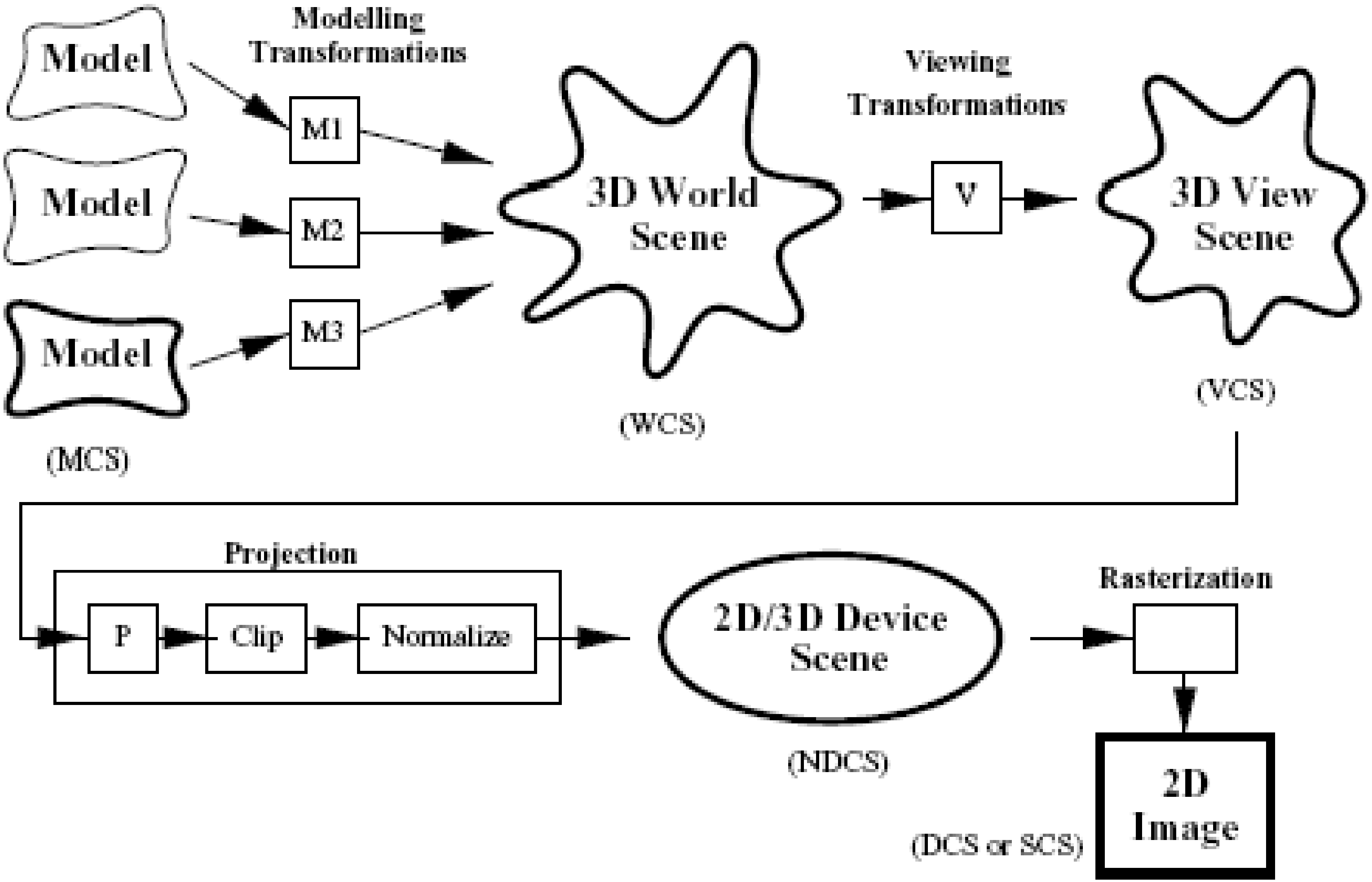


Light passes through



Light is blocked

Graphics rendering pipeline



Coordinate Representation

- MCS: Modeling Coordinate System.
- WCS: World Coordinate System.
- VCS: Viewer Coordinate System.
- NDCS: Normalized Device Coordinate System.
- DCS or SCS: Device Coordinate System or Screen Coordinate System.

Rendering primitives

- Models = {geometric primitives}
- Rendering primitives directly supported in H/W include
  - Points (pixels)
  - Line segments
  - Polygons (triangles)
- Modeling primitives include these, but also
  - Piecewise polynomial curves/surfaces
  - Implicit surfaces
  - Voxels ....

Basic rendering algorithms

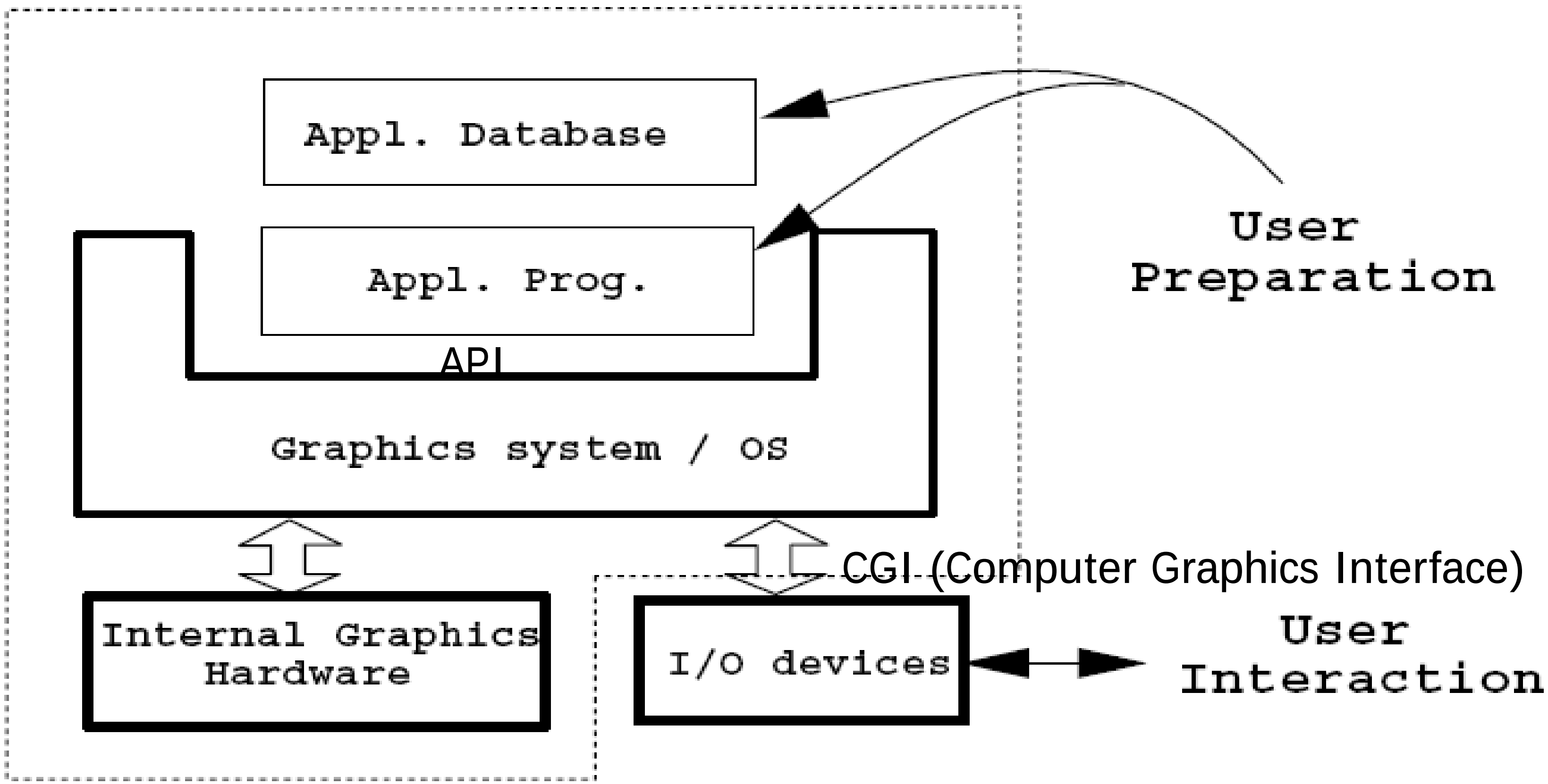
- Transformation : transform coordinates
- Clipping/Hidden surface removal
- Rasterization : convert a projected screen-space primitive to a set of pixels
- Picking : select a 3D/2D object by clicking an input device over a pixel location
- Shading and illumination
- Animation

Functions of a Graphic Package

Graphics Library such as OpenGL, DirectX

- Provide primitives for graphic description
- Build and maintain graphic representation model
- Provide primitives for viewing operations
  - use available H/W to perform such operations, if possible
  - perform viewing operations not possible at H/W
- Support user interaction with application program
- Interact directly with users to allow them modify viewing parameters, if possible

Graphics System



Graphics system: a library of graphics functions

Graphics S/W Packages

- How you use a Graphics package

  Application programmer's view

  vs. Package implementer's view

- Application Graphics Packages
  - Designed for nonprogrammer
  - Users can generate displays without worrying about how graphics operations work
  - E.g., PowerPoint, Medical software, CAD, Postscript

General Graphics Packages

- S/W evolution

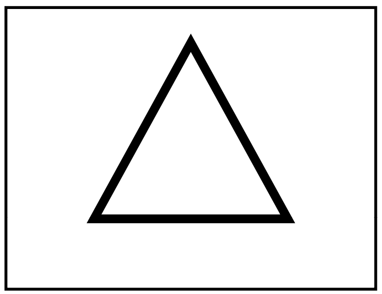
  device-dependent s/w $\Rightarrow$ device-independent s/w

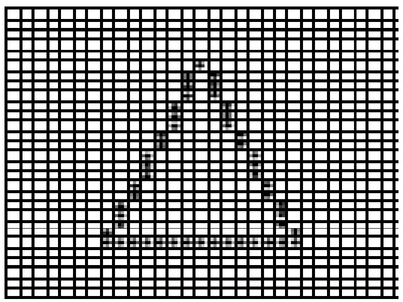
  $\Rightarrow$ standard s/w

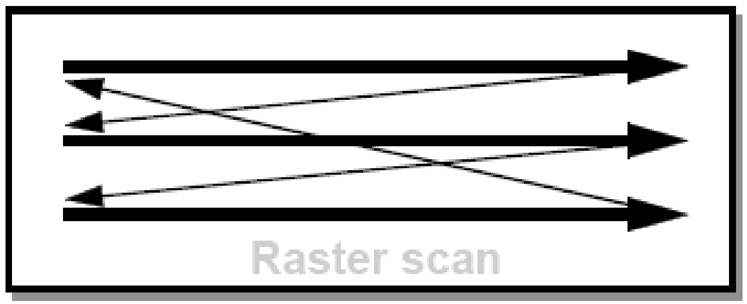
- Official Standards
  - Core: ACM SIGGRAPH 1977, U.S.
  - GKS : ANSI85, 2D, Europe
  - GKS-3D : ANSI88
  - PHIGS : ANSI88 - Hierarchical structures
  - PHIGS+ : ISO 92
- Non-official Standards
  - X Window System, PEX
  - Silicon Graphics OpenGL (1992)
  - MicroSoft DirectX
  - Sun Mircorsystems VRML

Vector and Raster

- Early displays were *vector* displays: a list of line endpoints was used to move the electron beam along some random path, a so-called *vector scan.*
- *Raster* displays (TVs etc) drive the beam in a regular pattern called a *raster scan.*
- Vector displays are almost extinct.
- Scan conversion: convert geometric primitives from *vector scan* descriptions (endpoints etc.) to *raster scan* descriptions (sets of pixels to turn on.)



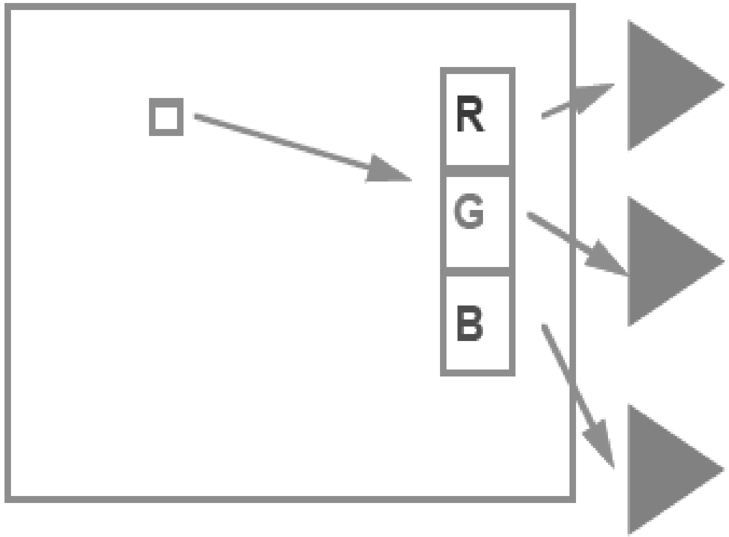




Frame buffers

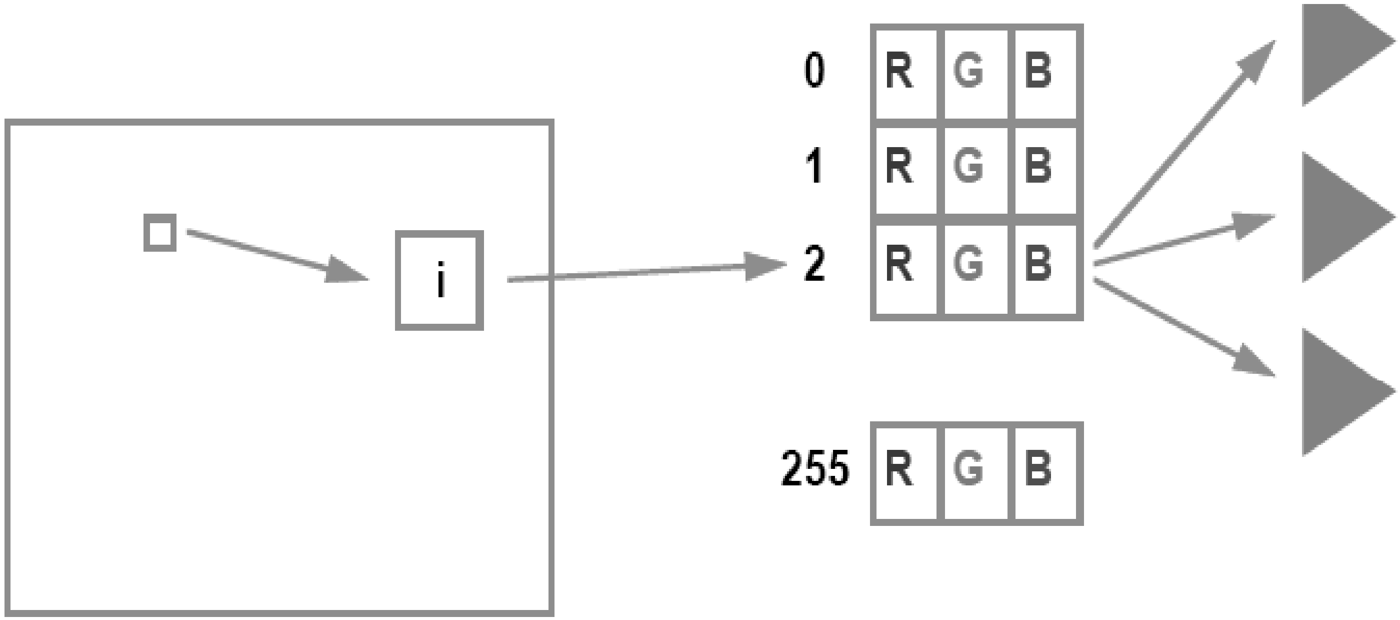
- The picture drawn by a raster or *bitmapped* display is stored in memory as a 2-D array of *pixels.* The 2-D array of pixel values is called a *frame buffer.* (Frame buffer, refresh buffer, raster, bitmap are used interchangeably.)
- Each row of pixels is called a scan-line or a raster line
- Frame buffer can be peripheral to the host or resident as part of the host computer's address space.
- The video hardware continuously scans the frame buffer.
- Types of display
  - B&W displays: 1 bit/pixel *(bitmap).*
  - Basic color displays: 8, 15, 16, or 24 bits.
  - High-end displays: 96 or more bits.

Full-color (RGB) displays



- For 24 bit color:
  - store 8 bits each of red, green, and blue per pixel.
  - E.g. (255,0,0) is pure red, and (255, 255, 255) is white.
  - 2^24 = 16 million colors.
- The video hardware uses the values to drive the R,G, and B guns.

CLUT(Color Lookup table)



A single number (e.g. 8 bits) stored at each pixel.

- Used as an *index* into an array of RGB triples.
- With 8 bits per pixel, you can get the 256 colors of your choice (except that the window system will probably reserve some).
- Simple things to fill up color-maps with:
  - ✓ A grey ramp (for grey scale pictures)
  - ✓ A bunch of random colors (for color drawings.)

Deeper Frame Buffers

- Some frame buffers have 96 or more bits per pixel. What are they all for? We start with 24 bits for RGB.
- Alpha channel: an extra 8 bits per pixel, to represent "transparency." Used for digital compositing. That's 32 bits.
- A Z-buffer, used to hold a "depth" value for each pixel. Used for hidden surface 3-D drawing. 16 bits/pixel of "z" brings the total to 48 bits.
- Double buffering:
  - For clean-looking flicker-free real time animation.
  - Two full frame buffers (including alpha and z).
  - Only one at a time is visible—you can toggle instantly.
  - Draw into the "back buffer" (invisible), then swap.
  - Can be faked with off-screen bitmaps (slower.)
  - 2 x 48 = 96.

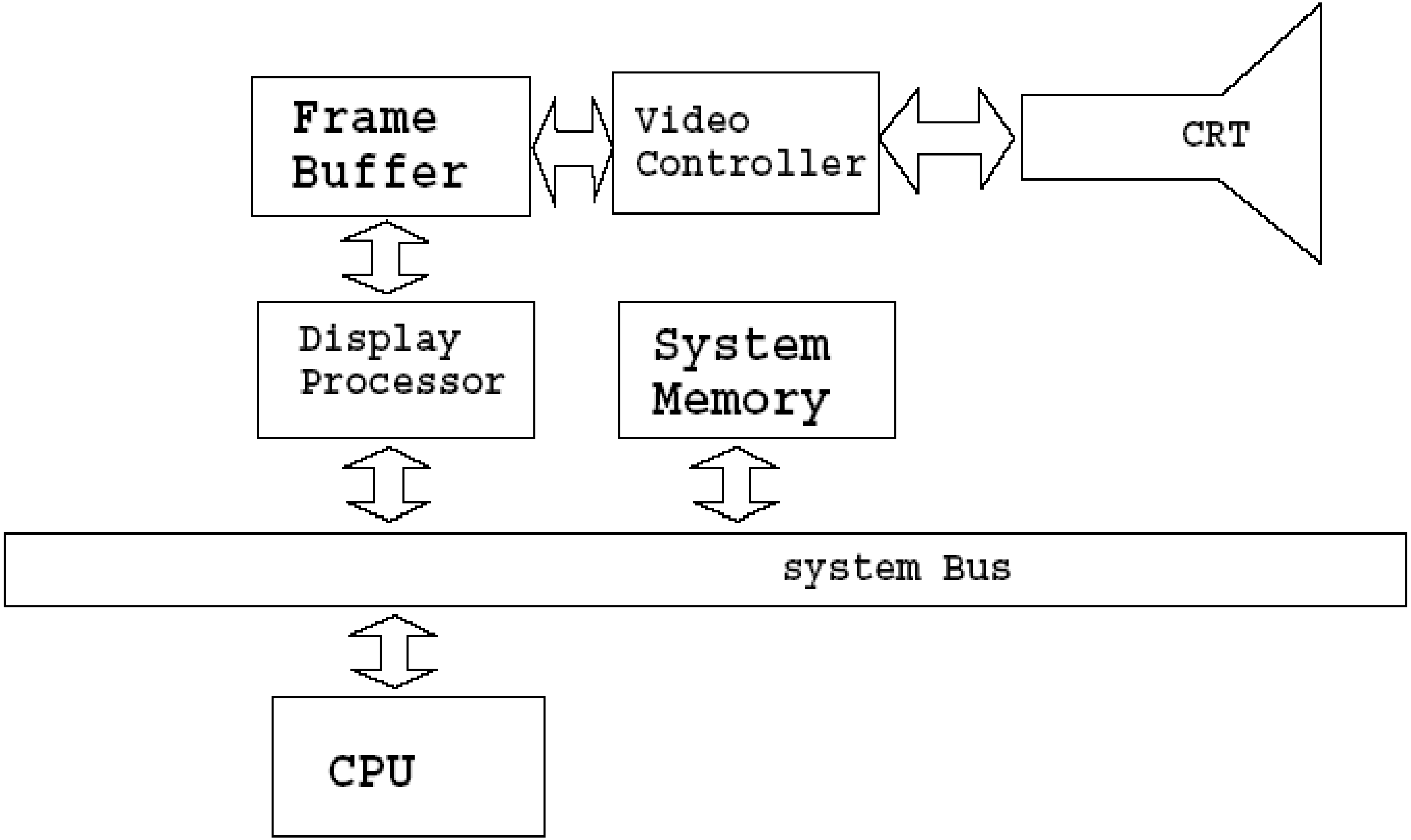
Display Resolution

- Spatial resolution: The maximum number of points that can be displayed without overlap on a CRT.
- Higher resolution gives a shaper image
- Intensity or color resolution depends on
  - frame buffer resolution
  - display H/W characteristics
  - sampling method

Raster CRT Display

- Dynamic display which means that the display needs to be refreshed in order to keep a pattern being displayed.
- Refreshing should be the responsibility of the device:
  - buffer memory (frame buffer)
  - a dedicated processor, called video controller, constantly copies color intensity values from the frame buffer onto screen, scanline by scanline. Such a process is called refresh.
  - Refresh rate = # of refreshes per second

Raster graphics system with a display processor



Interlacing

- Lower refresh rates result in flickering, which is the visually discernible disruption of light intensity on screen. An acceptable refresh rate is determined by the acuity of the human vision. Refresh rate must be matched with the excitement persistence of phosphor coating.
- Interlacing
  - a usual frame display rate : 60 Hz
  - divide a frame into even-numbered scan lines and odd-numbered scan-lines(each 1/60 sec)

    ⇒ whole frame takes 1/60 + 1/60 = 1/30 sec

Graphics Processor

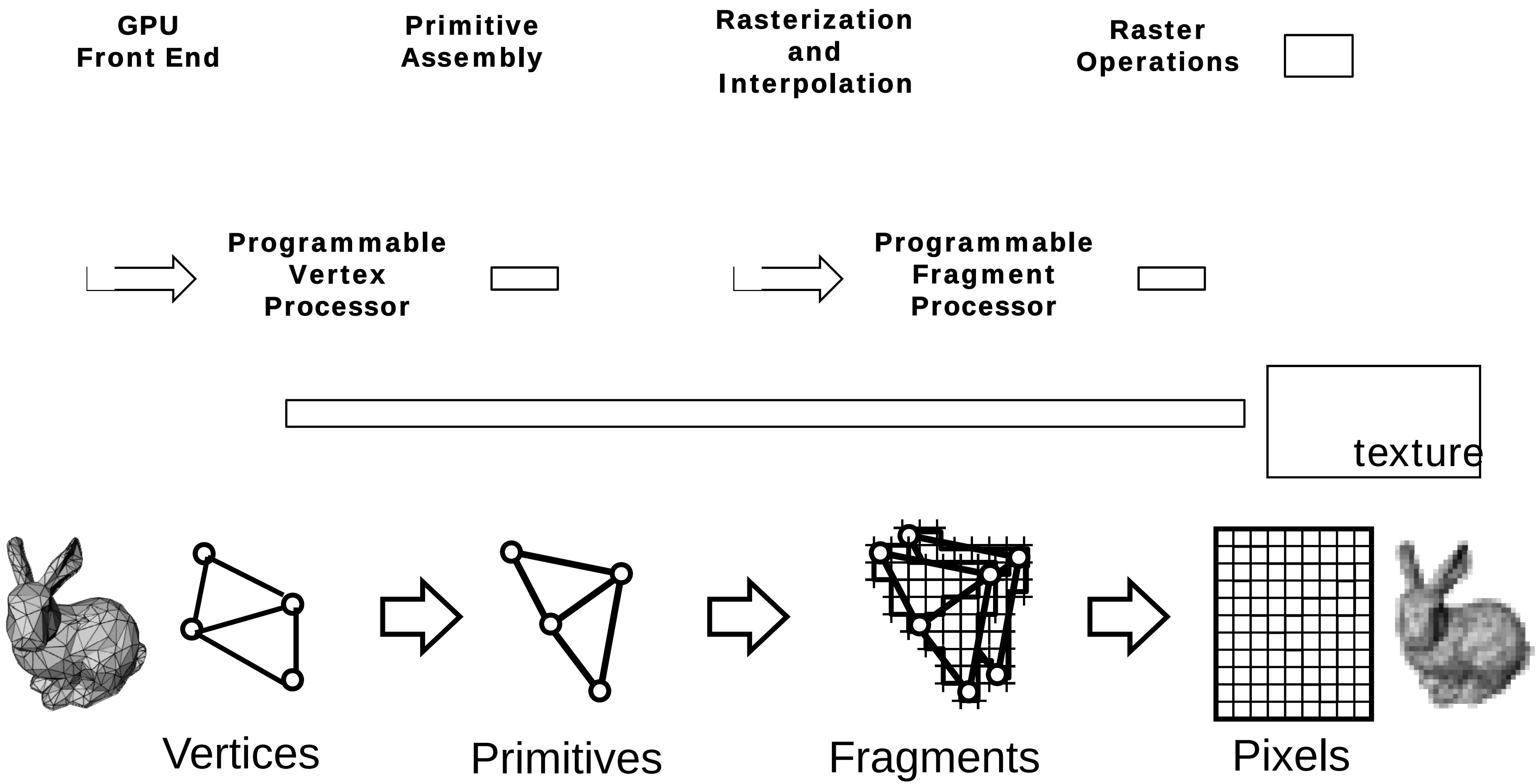
- Graphics Adapter: frame buffer + display controller (+ display processor)

  (e.g., VGA, XGA card)
- Common functions of display processor include
  - Z-buffer for visible surface determination;
  - line drawing;
  - clipping;
  - texture mapping;
  - ...

Graphics Hardware

- Graphics hardware is used on most PCs now
- Dedicated hardware 2D and 3D graphics processing unit (GPU)
  - nVIDIA : GeForce series (latest: GeForce 8800)
  - ATI : Radeon series (latest: Radeon HD2900)
- GPU’s highly parallel structure : up to 320 stream processors

Graphics Hardware (DirectX 9)



Why GPU?

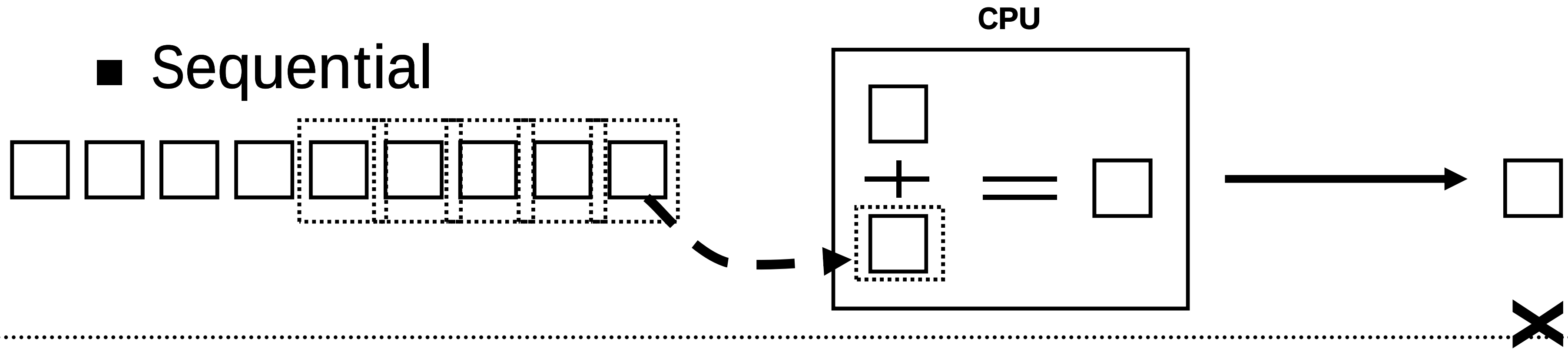
- Computational power exceeds CPU
  - CPU : 32.5GFlops, 17GB/s peak memory bandwidth
  - GPU : 518.4GFlops, 35.2GB/s peak memory bandwidth
- GPUs are getting faster
  - CPUs: annual growth 1.4×
    → decade growth : 60×
  - GPUs: annual growth > 2.3×
    → decade growth > 1000

Why GPU?

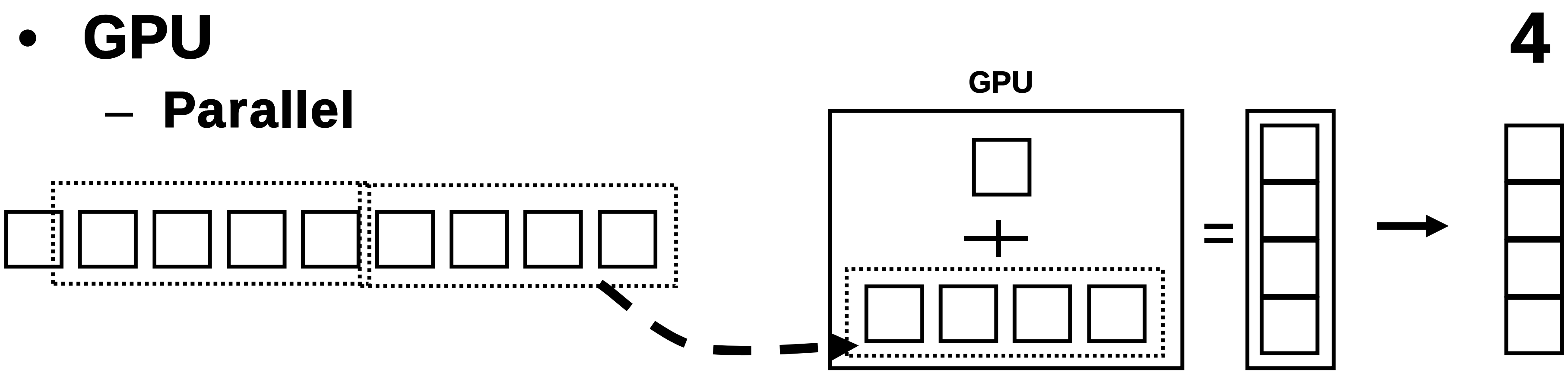
- Why GPU's performance is increased more rapidly than CPU's?
  - Semiconductor capability increasing
  - CPU
    - Optimized for sequential code
    - CPU's transistors are dedicated to supporting non-computational tasks
  - GPU
    - The highly parallel nature of graphics
    - Use additional transistors for computation
      - Higher arithmetic intensity with the same transistor count

Why GPU?

- CPU
  - Sequential



- **GPU**
  - **Parallel**



Output devices

- Stereoscopic viewing glasses: the user wears them to perceive stereoscopic view of 3D scenes displayed on screen.
  - Used in screen-based Virtual Reality (VR).
  - Has high resolution.
  - Limited head-movement.
- Head-mounted display (HMD): two small TV screens are embedded in a rack and placed in front of the two eyes.
  - It allows full-freedom head movement, and gives the feel of immersion.
  - Widely used in Virtual Reality (VR).
  - A tracking system is used to report the position of HMD in 3D space.
- Plotter

- Laser printers
  - Use laser beam to create a charge distribution on a drum coated with a photoelectric material.
  - Toner is applied to the drum and then transferred to paper.
  - To produce a color copy, the process is repeated three times for red, green and blue colors.

- Ink-Jet printers
  - Spray electrically charged ink on paper
  - Ink stream is deflected by electric field
  - Multiple jets of different color ink can shot simultaneously for producing color drawings

Input devices

- Keyboard
- Mouse
- Trackball: a 2D input device, usually used on a mouse or a lap-top computer.
- Space ball: hand held, non-movable. It uses a strain gauge to detect pull, push, and twist applied to the ball, and translate them into 3D locations. Used for navigation in virtual environments, CAD, etc.
- Head Mounted Display: Although primary a display device, it can also track positionand orientation
- Joystick: similar to the space ball. Can be movable and non-movable.

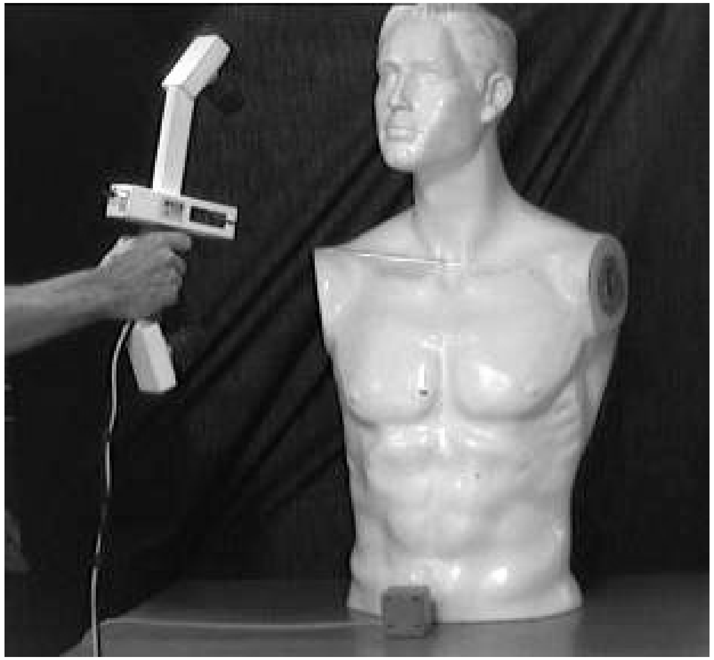
Space ball

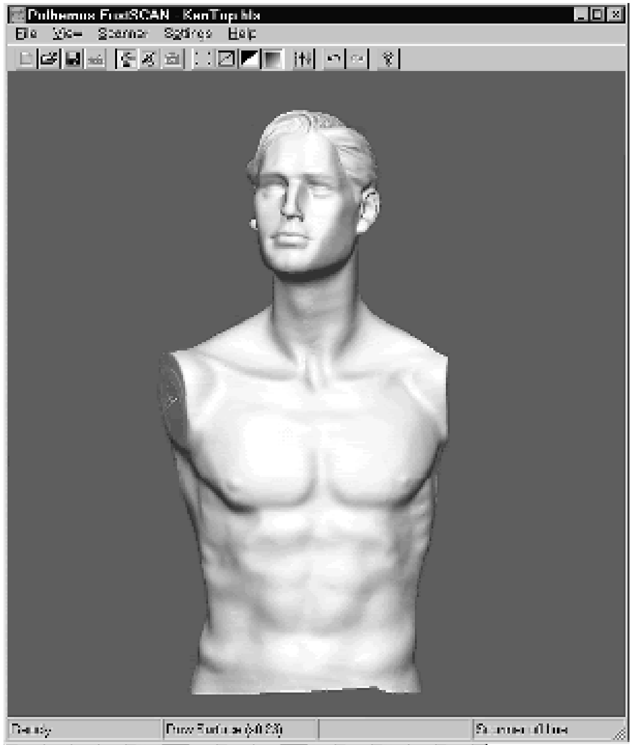
Input devices

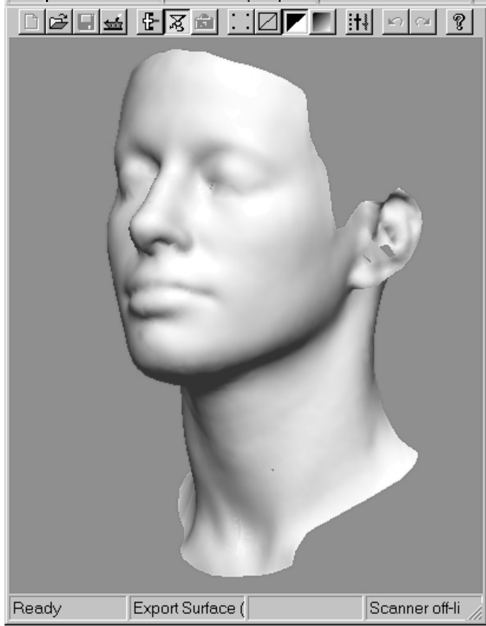
- Data glove: a glove with sensors. Used to control a virtual hand for grasping, dropping, and moving an object in a virtual environment.

- Image scanner: input still picture, photo, or slides as images into computer.
- Touch panel: highly transparent and embedded over a display surface.
- Digital camera: directly stores photo shots as images on a diskette.
- Digital video recorder: input a video clip in digital form; often used for teleconferencing.

➢ 3D handheld laser scanning digitizer

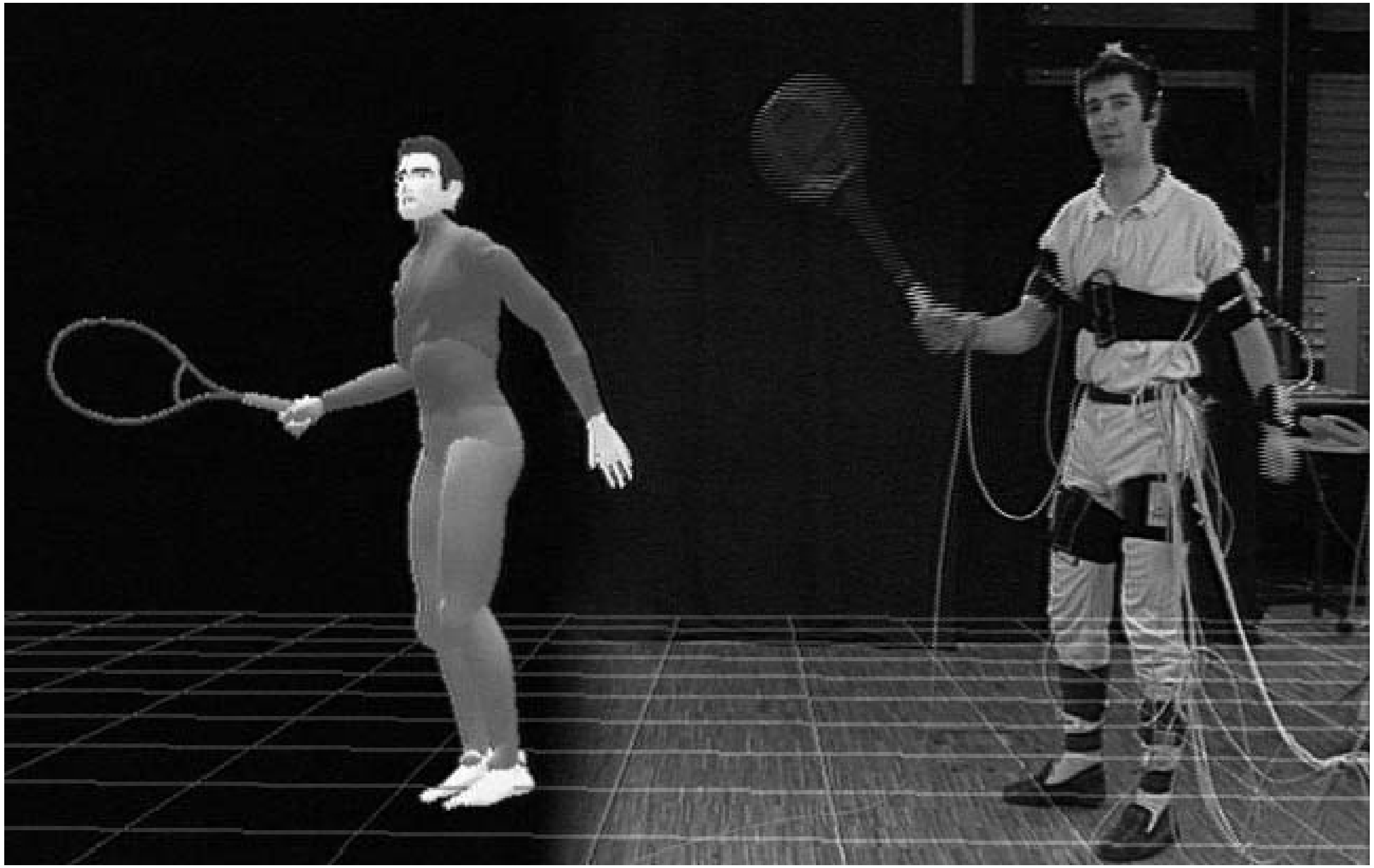






Long Range Laser Scanning

- Motion Tracking sensors



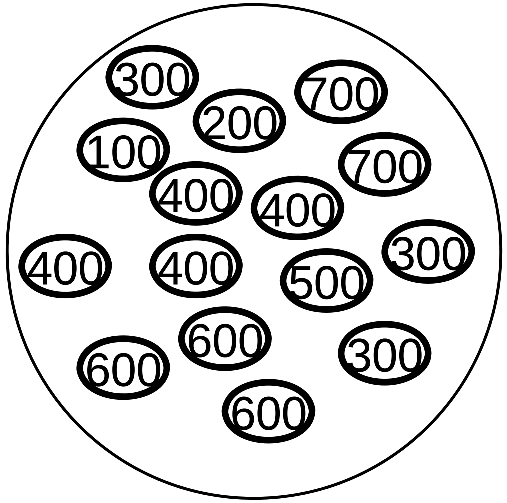
Color and Intensity

- light : made up of many little particles(photons)

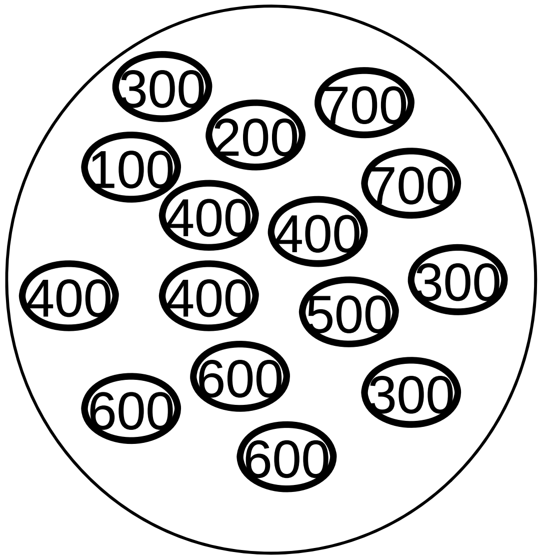
  ← particle model

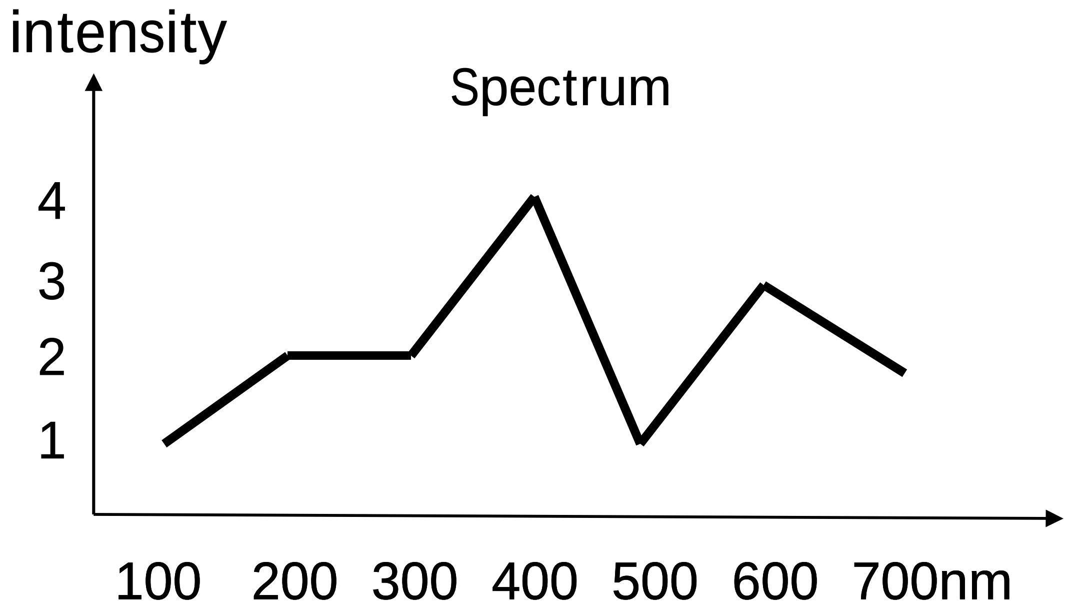
  (cf. wave model)

- color : the frequency of a photon



Intensity



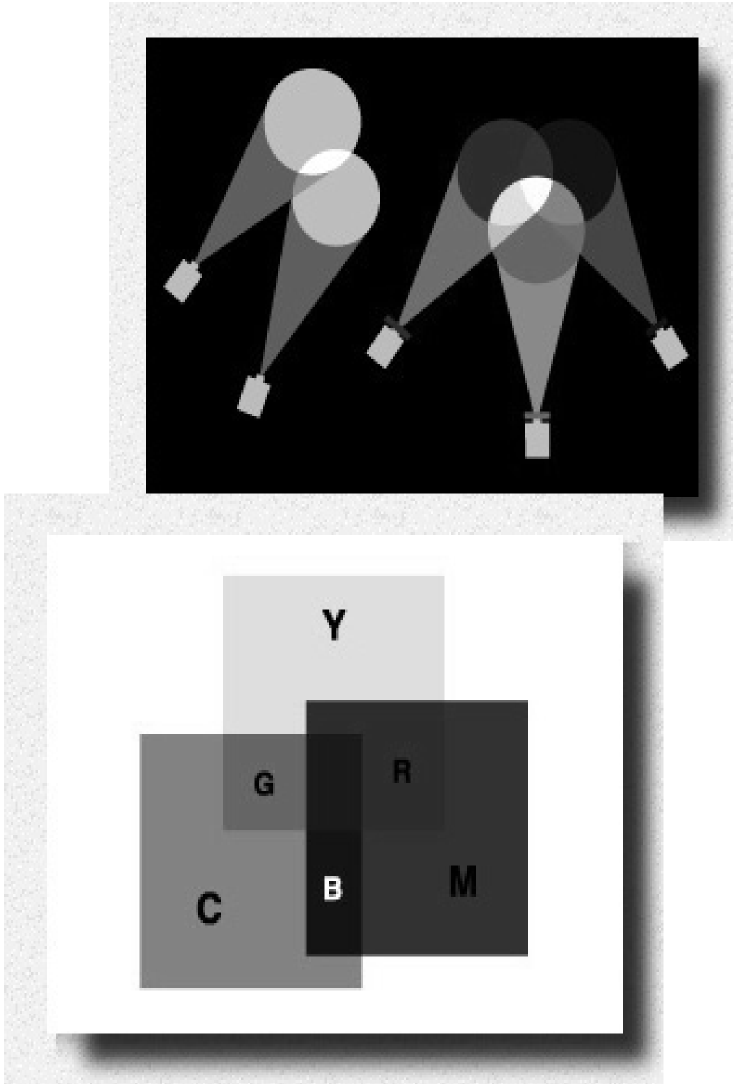


- intensity : the amount of light, or the amount of a particular color actually reflected or transmitted from a physical object.

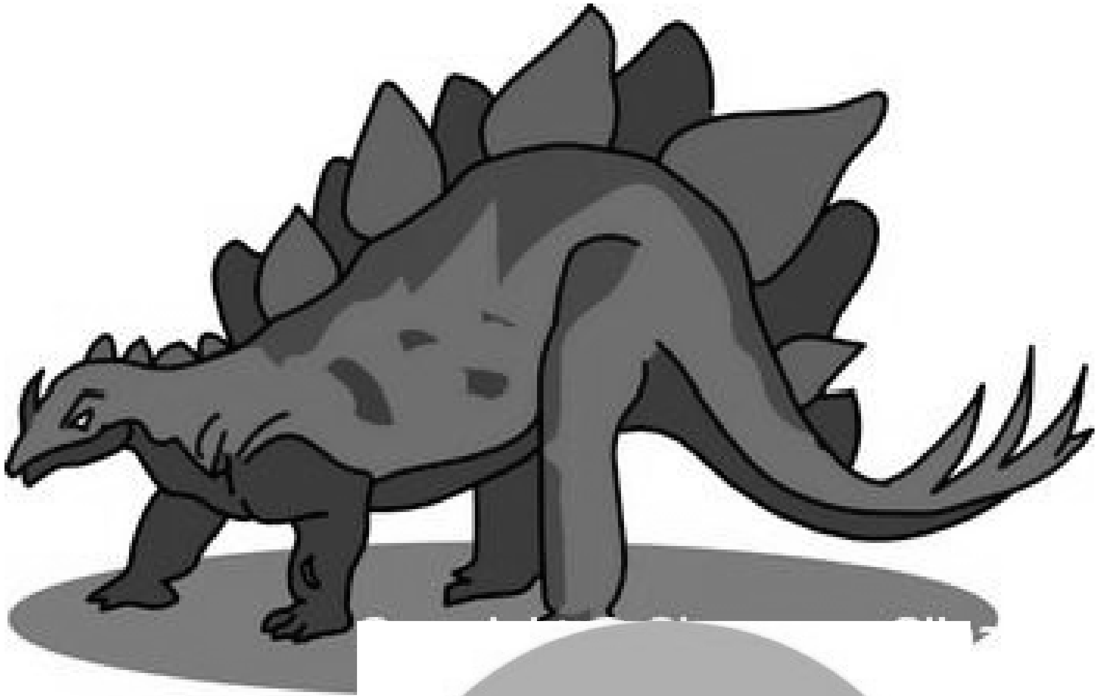
cf) brightness : measured intensity after it is acquired, sampled, and observed (with our eye)

Color Model

- RGB color model : red, green, blue
  - additive model
  - illumination based - the color that reaches your eye from your monitor depends on the illuminating light it emits.
- CMYK : cyan, magenta, yellow, and black
  - subtractive model
  - reflection based



CG History



Directions in Computer Graphics

- Plotting
- Interactivity
- Real-Time Manipulation
- Image-Realism (Photorealistic rendering)
- Real-Time Rendering
- Scientific Visualization

History

Motivated by hardware evolution and the availability of new devices

- 1950's : First military applications of graphics
  - Whirlwind, built in early 50’s at MIT, cost $4.5 million and could perform 40,000 additions/second.
- 1960's: Popularization of the storage tube by Tektronix

  direct-view storage-tube(DVST) display terminal

<u>DVST</u>

- ✓ $12,000 - $15,000
- ✓ no refreshing is needed
- ✓ high resolution w/o flicker
- ✓ no partial erasing, no color mode

History

- 1963
  - Sketchpad interactive drawing system
    by Ivan Sutherland(MIT)
    - introduction of interactive computer graphics data structures for storing symbol hierarchies, interaction technique - keyboard and light-pen
  - Douglas Engelbart invents the mouse
  - Steve Coons - Surface patch technique

Sketchpad in 1963. Note use of a CRT monitor, light pen and function-key panel.

History

- Mid 1960s : Industry starts to use interactive computer systems but primary batch mode and too much cost
- 1970's : Turnkey systems and raster displays images
- 1977 - Apple II
- Early 1980s : Introduction of PC (Macintosh, IBM PC)
  - OOP paradigm UI such as Smalltalk80, Macintosh UI
  - Workstations are more common
  - Performance-price ratio takes off
- Mid 1980's : Emergence of graphics standards

History

- Luxo Jr. (1986) is the first three-dimensional computer animated film to be nominated for an Academy Award

- Late 1980's : Evolution of advanced GUI's and visualization environments

History

- 1990's
  - Low price, high performance
  - Increasing demand for higher quality graphics
  - GUI and other graphics intensive applications.
  - 1995: Toy Story (Pixar and Disney), the first full length fully computer-generated 3D animation

    Since then : Toy Story (1995), A Bug's Life (1998) and Toy Story 2 (1999), and …
  - Late 90’s: interactive environments, scientific and medical visualization, artistic rendering, image based rendering, etc.

History

- 2000's
  - PC, Natural interface using speech, gestures and facial expressions
  - Real time photorealistic rendering on PC
  - Ubiquitous computing
  - Moved from texture-mapped rendering to programmable pixel shading in pursuit of cinematic realism

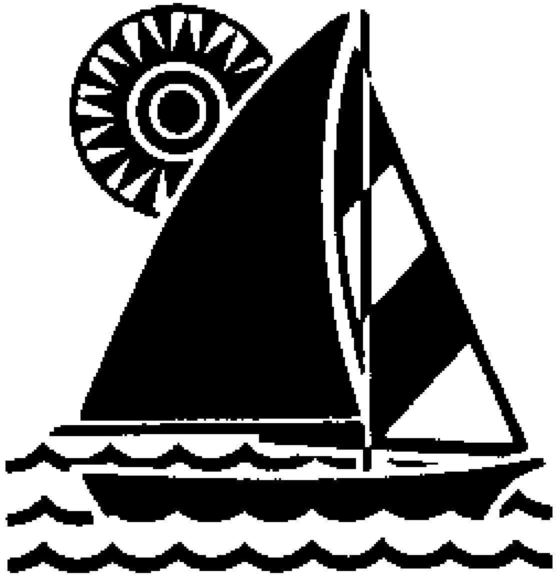
History : shaded image

- Since mid-1970's : the development motivation has been photo-realism or TV image like a graphics image
- Photo-realism depends on how we calculate light-object interaction
- Local/Global reflection models
  - Groud shading (1971)
  - Phong local reflection model(1975) :most popular
  - ray tracing (1980) - specular interaction
  - radiosity (1984) - diffuse interaction

Future of Computer Graphics

- What *is* CG? is a wrong question
- *Where it can be found*? is better
  - CAD/CAM - 90% of cars are done using CG
  - DTP - newspaper and magazine
  - GUI - do you use Windows…?
  - Film effects - very attractive, but not important
  - Games - i.e., $$$$
  - Video editing - Local TV studios, TV news,
  - Virtual reality- CAD/CAM, visualization
  - and many many more

How we draw, edit and save a picture



Read Chap. 15

Graphics File Formats

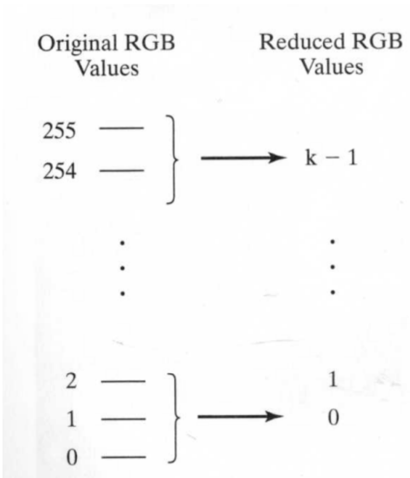
- Image-File Configurations
- Color-Reduction Methods
- File-Compression Techniques

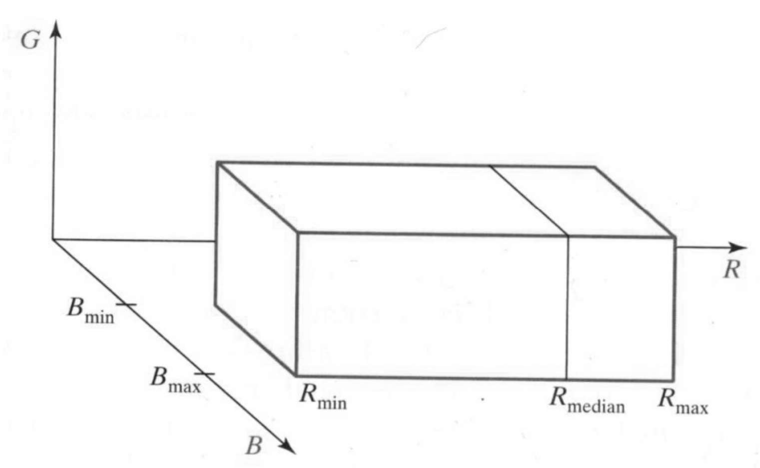
Image-File Configurations

- Raw data (or Raw raster file)
  - Uncompressed raster-graphics file
- Header of image file
  - Information about the structure of the file
  - File size, depth, compression method, color range, background color, etc.
  - For compressed files, tables for decoding and display

Color-Reduction Methods

- Color-reduction
  - Reduce the number of colors used in the display of an image
  - Replaces one discrete set of colors with a smaller set
- Uniform Color Reduction
- Popularity Color Reduction
  - Select the *k* most frequently occurring colors in the image file
- Median-Cut Color Reduction
  - Subdivide the color space for the image file into *k* subregions





File-Compression Techniques

- Lossless compression vs. Lossy compression
- Run-Length Encoding
  - Store each sequence of repeated values as the single file value along with the number of repetitions

{20, 20, 20, 20, 99, 68, 31, 40, 40, 40, 40, 40, 40, 40, 40, ...}

{4, 20, -3, 99, 68, 31, 8, 40, ...}

File-Compression Techniques

- LZW Encoding
  - Replace the patterns with codes
  - Substitutional algorithm or dictionary-based algorithm

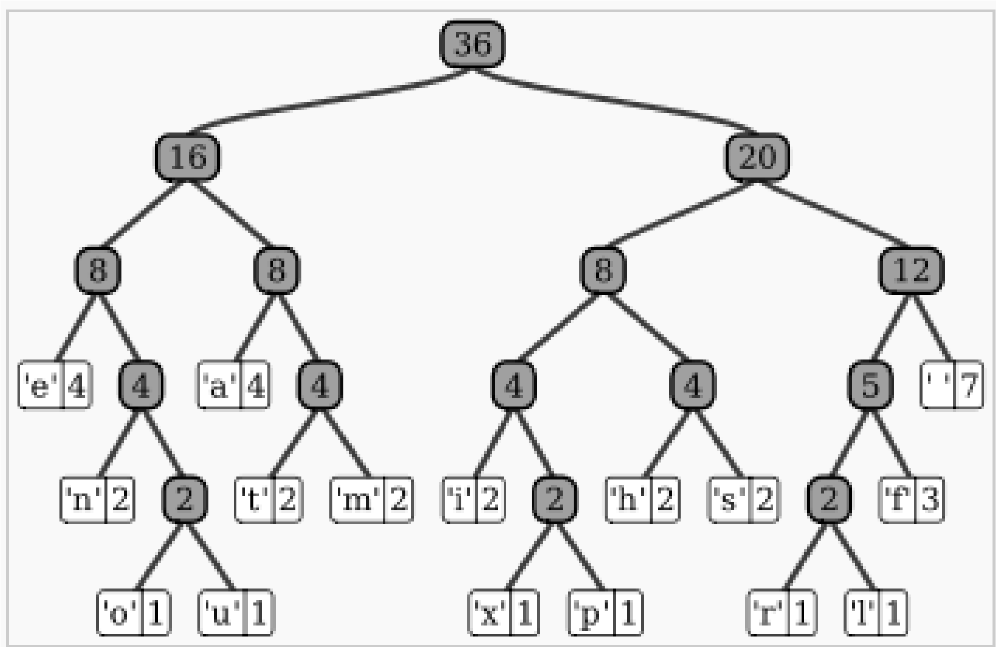
    {128, 96, 200, 30, 10, 128, 96, 50, 240, 200, 30, 10, ...}

    {c1, c2, c1, c3, c2, ...} or {c1, c2, c1, 50, 240, c2, ...}

- Other Pattern-Recognition Compression Methods

File-Compression Techniques

- Huffman Encoding
  - Assign the shortest code to the most frequently occurring value, and the longest code to the least occurring value



Char	Freq	Code
space	7	111
a	4	010
e	4	000
f	3	1101
h	2	1010
i	2	1000
m	2	0111
n	2	0010
s	2	1011
t	2	0110
l	1	11001
o	1	00110
p	1	10011
r	1	11000
u	1	00111
x	1	10010

File-Compression Techniques

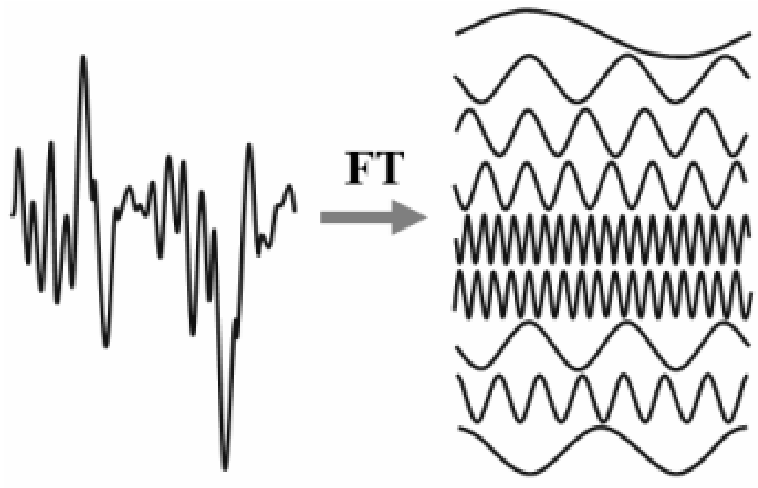
- Arithmetic Encoding
  - Frequency count is used to obtain numerical codes
  - Boundary values for the subintervals are used to encode and decode the sequences within the file

File Value	**Frequency Count**	**File Fraction**	**Unit-Interval Range**
A B C	16 24 40	0.20 0.30 0.50	0.00 - 0.20 0.20 - 0.50 0.50 - 1.00
Total	80	1.00	

Sequence	**Unit-Interval Range**	**Sequence**	**Unit-Interval Range**
AA AB AC ...	0.00 - 0.04 0.04 - 0.10 0.10 - 0.20	... CA CB CC	 0.50 - 0.60 0.60 - 0.75 0.75 - 1.00

File-Compression Techniques

- Discrete Cosine Transform
  - Encoding



$$V_j' = c_j \sum_{k=0}^{n-1} V_k \cos\left[\frac{(2k+1)j\pi}{2n}\right], \quad \text{for } j = 0, 1, \ldots, n-1$$

$$c_j = \begin{cases} \dfrac{1}{\sqrt{n}}, & \text{for } j = 0 \\ \sqrt{\dfrac{2}{n}}, & \text{for } j \neq 0 \end{cases}$$

{215, 209, 211, 207, 192, 148, 88, 63}

➔ {471.29, 143.81, -67.76, 16.33, 7.42, -4.73, 5.49, 0.05}

  - Decoding

$$V_k = \sum_{j=0}^{n-1} c_j V_j' \cos\left[\frac{(2k+1)j\pi}{2n}\right], \quad \text{for } k = 0, 1, \ldots, n-1$$

# of Terms	Inverse Discrete Cosine Transform Vales							
4	212.63	211.85	211.53	207.42	188.43	147.65	95.47	58.02
5	215.26	209.23	208.91	210.04	191.06	145.02	92.84	60.64
8	215.00	209.00	211.00	207.00	192.00	148.00	88.00	63.00

Bit-Mapped vs. Object-Oriented Graphics

- Painting programs
  - bit-mapped representation
  - e.g., MacPaint
- Drawing programs
  - object-oriented representation
  - e.g., AutoCAD

Bit-Mapped Graphics

- Paint Mode
- Bit-mapped memory - represent graphical images and patterns by assigning a block of memory for the direct storage of the intensity patterns
- Objectiveness of a line, polygon, or brush stroke is lost
- Limitations
  - pixel democracy - all pixels are created equal once, they are set in a bit-mapped image → slow modification
  - no support of images requiring precision or numerical dimensioning device dependency

Object-Oriented Graphics

- Draw Mode
- Mathematical representation of lines, rectangles, ovals, Bezier curves, and so on.
- Objectiveness is maintained
  - Objects designed may have a hierarchical structure
  - Easily editable
- Difficulties
  - more difficult to use
  - no support of painting tools

Image File Formats – Pixel-Mapped

- GIF (Graphics Interchange Format)
  - the CompuServe Information Service and F&R Block Company
  - copyrighted bitmap format
  - uses compression
  - can store only 256-color images, any size
  - 9.9 megabyte for 1943x1702 24-bit RGB color image
- PNG (Portable Network Graphics)
  - a royalty-free GIF and LZW (maybe also TIFF) replacement
  - Upto 48 bits/pixel
  - superior lossless compression
  - 6.5 megabyte for 1943x1702 24-bit RGB color image
  - http://www.libpng.org/pub/png/

Image File Formats – Pixel-Mapped

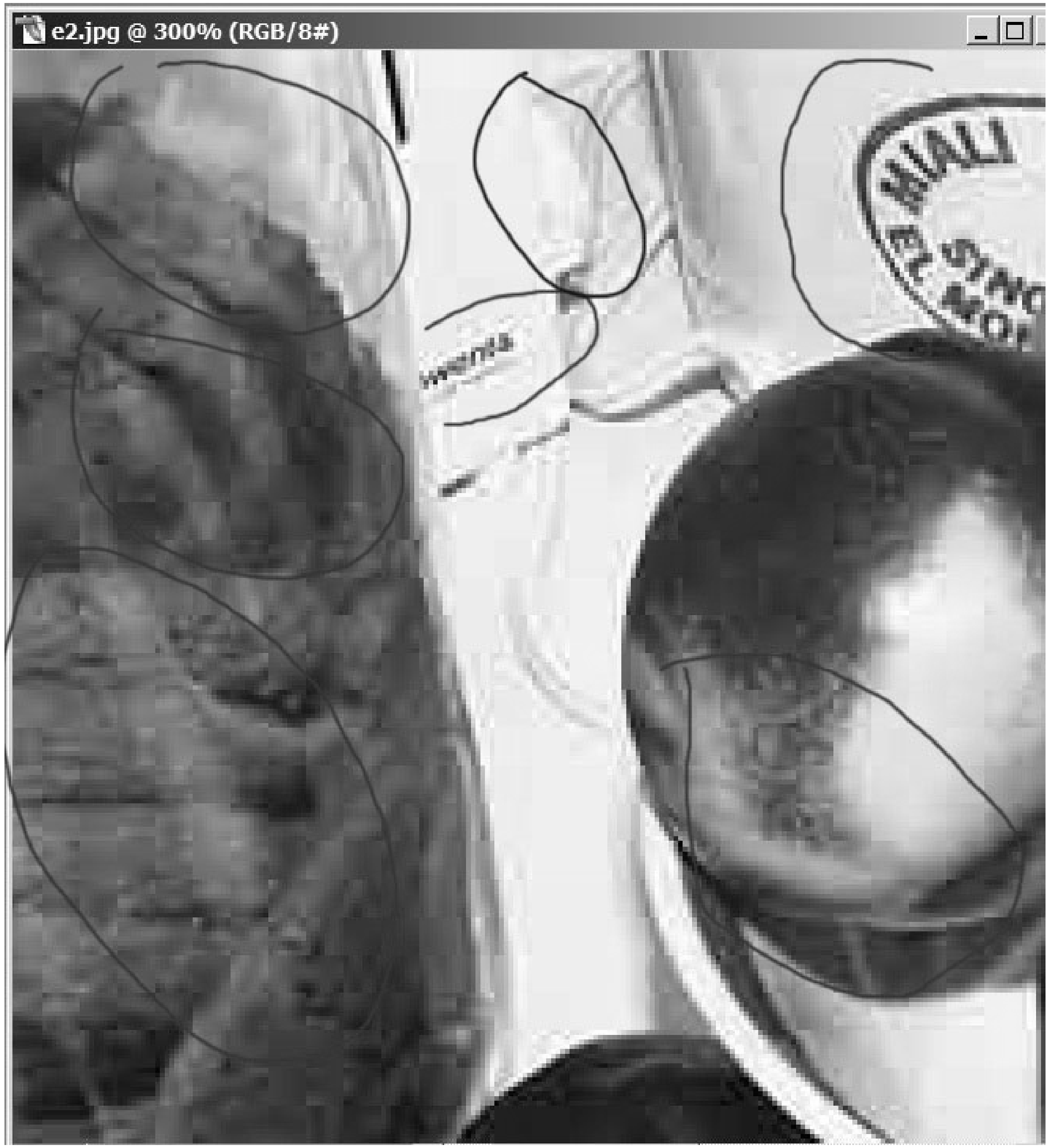
- TIFF (Tag-based Image File Format)
  - Aldus Corp. and Microsoft to support digital scanner manufacturers and desktop publishing systems to describe and store raster image data
  - TIFF is a popular format for high color depth images, along with JPEG and PNG
  - run-length encoding with compression (also LZW)
  - independent of OS, processors, compilers, and filing systems
  - become a standard for image storage and communication

Image File Formats
- Pixel-Mapped

- JPEG (Joint Photographic Experts Group)
  - international compression standard (1992)
  - high compression rate can be acquired by removing the following redundancy in an image:
    - spatial (between neighboring pixels),
    - spectral (between color planes),
    - temporal (between adjacent frames in a sequence)
  - highly lossy compression (in general, 5:1 and 15:1)
    But, objectionable blocking artifacts may occur.
  - poor lossless compression efficiency (less than 3)
  - lossy compression method is limited to input images with maximum bit depth of 8bits/pixel.
  - lossless support 2 to 16 bits/pixel.
  - no support for true-color

JPEG artifacts

TIFF



JPEG

Image File Formats
- Pixel-Mapped

- JPEG 2000
  - new international compression standard (2002.1)
  - roughly 20% on average higher compression efficiency than JPEG
  - new functionalities:
    - integrated lossy/lossless compression
    - region-of-interest(ROI) encoding
    - Multi-resolution capability
    - Progressive transmission by pixel and resolution accuracy - progressive decoding
    - etc.

JPEG 2000 Applications

- Consumer applications such as multimedia devices (e.g., digital cameras, personal digital assistants, 3G mobile phones, color facsimile, printers, scanners etc)
- Client/server communication (e.g., the internet, Image database, Video streaming, video server, etc.)
- Military/surveillance (e.g., HD satellite images, Motion detection, network distribution and storage, etc..)
- Medical imagery (PACS)
- Storage of motion sequences (e.g., digital cinema, HD digital Camcorder).
- Remote sensing, digital libraries/archives, and E-commerce.

Image File Formats – Pixel-Mapped

- EPSF: Encapsulated PostScript File Format
  - Adobe Systems Incorporated
  - importing and exporting PostScript language files
  - grayscale or color
  - usually ASCII
  - No compression
  - can be mix of raster and geometric data

Image File Formats – Pixel-Mapped (Comparison)

	BITS PER PIXEL	FILE SIZE	COMMENTS
JPEG	24	small	lossy, good for archives
TIFF	8,24	medium	good
GIF	1,4,8	medium	no good for colorful images
EPSF	1,2,4,8,24	huge	good for printing

Image File Formats – Object-Oriented

- Store a description of how to draw the image
- CAD File Formats
  - DXF/AutoCAD
    - AutoCAD
    - de facto industry standard
    - drawing exchange files
  - IGES (Initial Graphics Exchange Specifications)
    - ANSI standard
    - used by W/S, minicomputer, and mainframes based CAD

DirectX Graphics vs. OpenGL

DirectX Graphics

- Microsoft
- Microsoft Windows
  - DirectX is better optimized for hardware 3D acceleration on the Windows platform
- Latest version : Direct3D 10
- Object Oriented Programming friendly
  - COM and .NET based

OpenGL

- SGI
- Multi-platform : An implementation is available on most modern OS
- Latest version : OpenGL 2.1
- Not Object Oriented (Includes and Libraries)

OpenGL 2 vs. Direct3D 9/10

	OpenGL 2	Direct3D 9	Direct3D 10
Operating System Support	Windows, MacOS, BeOS, *nix, others	Windows (9x, 2000,xp)	Windows Vista
API Specification	OpenGL Specification	SDK Documentation	SDK Documentation
API Mechanism	includes and libraries	COM	OS Integrated (WDDM Driver)
Source Implementation Available	Yes	No	No

OpenGL 2 vs. Direct3D 9/10

	OpenGL 2	Direct3D 9	Direct3D 10
Fixed-Function Shaders	Yes	Yes	No
Programmable Shaders	Yes	Yes	Yes
Parametric Curve Primitives	Yes	Yes	Yes
Parametric Surface Primitives	Yes	Yes	Yes
Matrix	Row major order	Column major order	Column major order
Coordinate System	Left-handed	Right-handed	Right-handed

OpenGL 2 vs. Direct3D 9/10

	OpenGL 2	Direct3D
Pros	▪ Familiar to traditional C programmers ▪ Industrial standards	▪ Can manage hardware resources directly ▪ Early adoption of new technologies and hardwares
Cons	▪ Rigid specification ▪ Late adoption of new technologies ▪ Incompatibility between extensions of vendors	▪ Strongly platform-dependent (Windows only) ▪ Hard to learn API and program an application

Next Topics

- We have finished Chap 1 & 2.
- Next topic is how to find pixels corresponding to graphic primitives.