1. Introduction to Graphics

1.1 What is Computer Graphics?

1.2 Applications

1.3 How to get a picture onto the screen...

1.4 PC Graphics Hardware

1.5 PC Graphics – Logical Organisation

1.1. What is Computer Graphics?

Computer graphics (CG) is the field of visual computing, where one utilizes computers both to generate visual images synthetically and to integrate or alter visual and spatial information sampled from the real world.

[http://en.wikipedia.org/wiki/Computer_graphics]

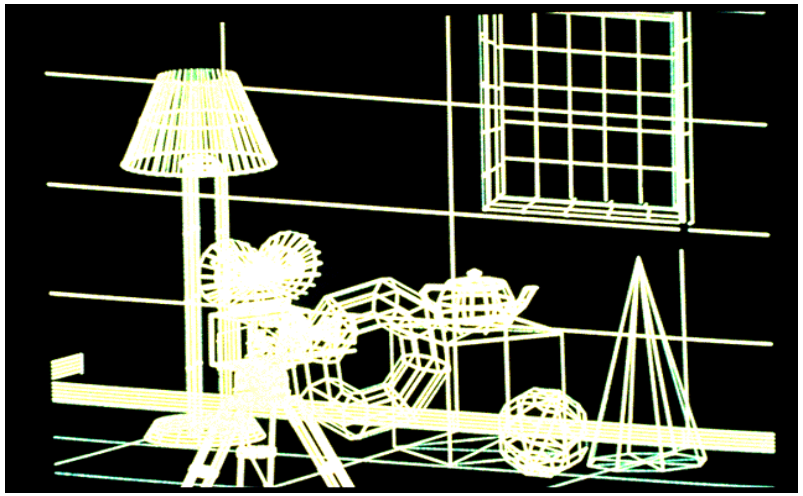
OUTPUT

INPUT	descriptions	images
descriptions		Computer Graphics
images	Computer Vision	Image Processing

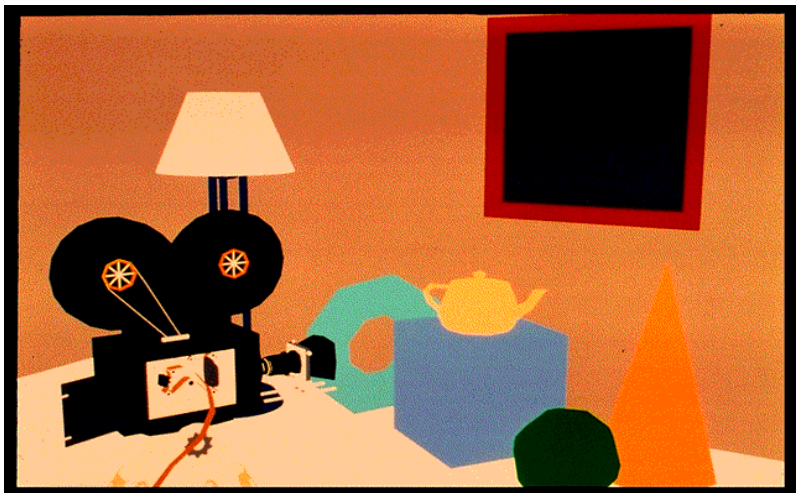
The Evolution of Computer Graphics

- 2D Rendering
  - 2D geometry (curves, 2D objects, ..), drawing algorithms
- 3D Rendering
  - 3D geometry (surfaces, 3D objects, …), lighting, view transformations, hidden surface removal, rendering algorithms, …

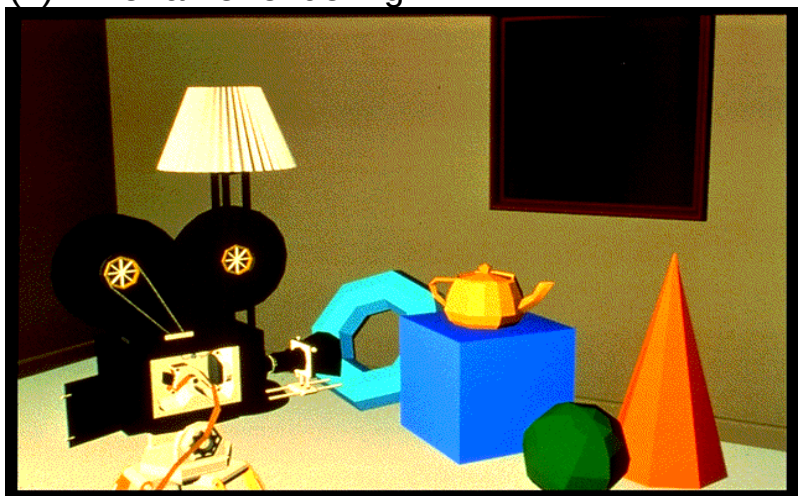
Improving the realism of a rendered scene requires increasingly complex techniques – the following slides give an example:



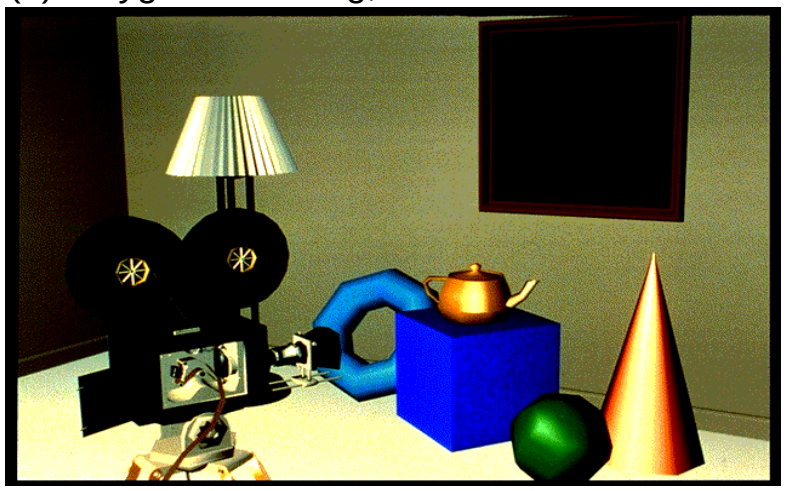
(1) Wireframe rendering



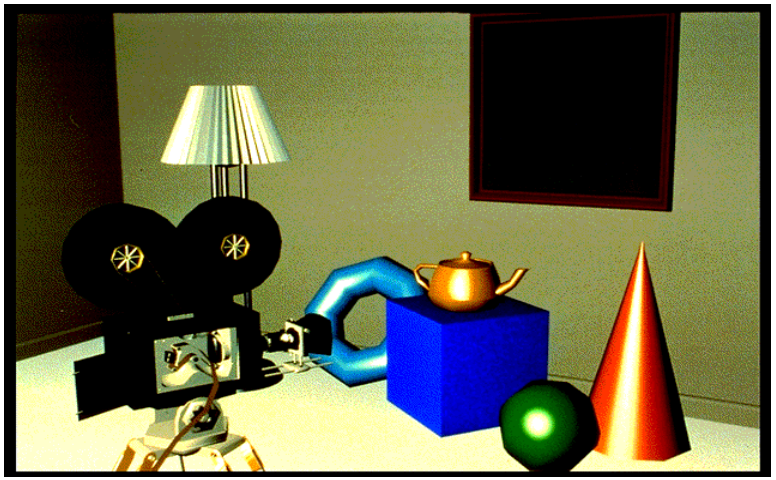
(2) Polygon rendering, Hidden surface removal



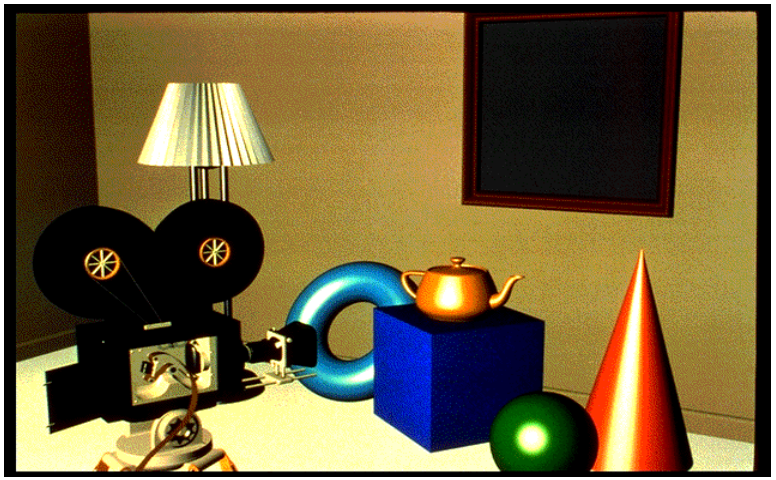
(3) Flat shading



(4) Gouraud shading



(5) Phong shading



(6) Curved objects

(7) Multiple light sources

(8) Texture mapping

(9) Shadows, displacement mapping

(10) Reflectance mapping

The Evolution of Computer Graphics (cont'd)

- Animation
  - Adding a time dimension (4D)
  - Simulation becomes part of CG

Alien song - http://www.hash.com/users/navone/HTML/MakingAlienSong.htm

- Interactive Computer Graphics
  - Animation at interactive frame rates
  - "Immersion in a virtual world"
  - Computer games, medicine, scientific visualization, ...

Crysis

The Evolution of Computer Graphics (cont'd)

- Virtual Reality (VR)
  - "Visual immersion" → complete sensory immersion (ideally)
  - Head mounted display + haptic feedback + sound + ...
- Augmented Reality (AR)
  - enhance experience of a real environment by augmenting it with computer generated information

1.2 Applications of Computer Graphics

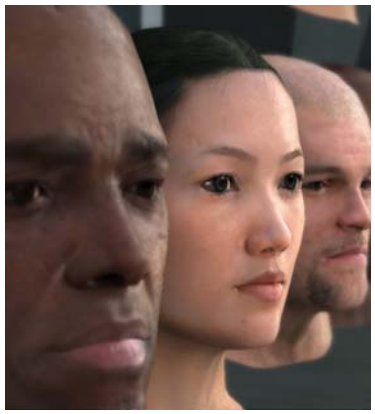
- Entertainment
  - Movies - CGI (Computer Generated Imagery)
  - Computer Games
- Engineering/Science/Medicine/Education
  - CAD/CAM (Computer Aided Design/Manufacturing)
  - Biomedical and Scientific Visualization
- Architectural Design / Landscape Planning
- Advertising / Commerce
- Military / GIS

Movie Production

- US$ 30 Billion dollar industry
- CGI (Computer generated imagery) popular since:
  - often cheaper than:
    - creating 3D models
    - using animatronics
    - hiring stuntmen
    - using extras for crowd scenes
  - Can create scenes which don't exist in reality
  - Pushes the boundaries - Source of constant innovation

Computer Games

- > US$ 30 Billion dollar industry
- Driving force in CG
  - Interactivity
  - Graphics hardware
  - Networking/Collaboration
  - Low-cost solutions
- Game engines are extremely complex software systems
- Play games!!!
  - Try to understand the techniques being used
  - Try to write your own games

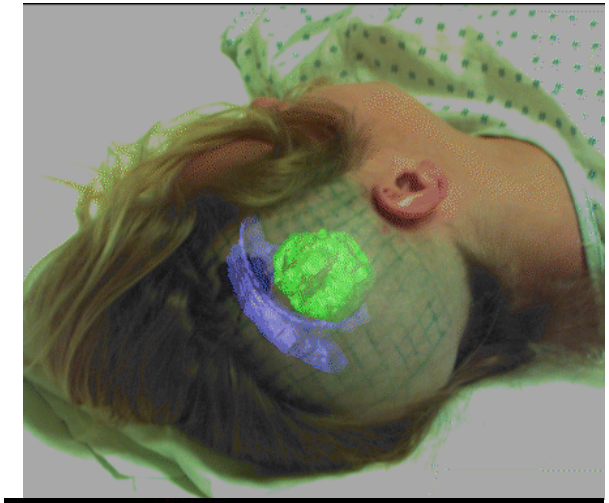


Virtual Worlds

- Virtual and Augmented Reality are becoming a serious business, e.g. “Second Life”
- Attract many non-traditional users
- Allow people to create their own models
- Innovative online commerce solutions

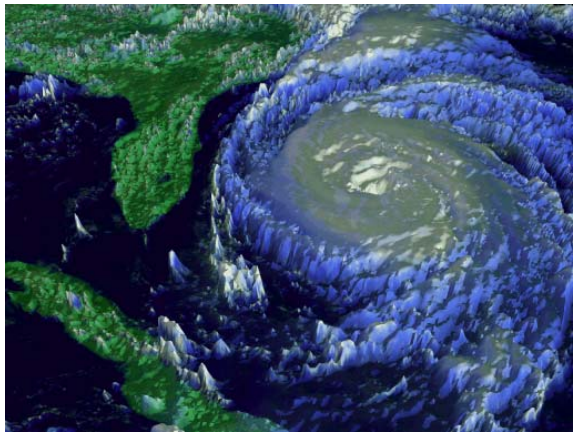
Medical Imaging

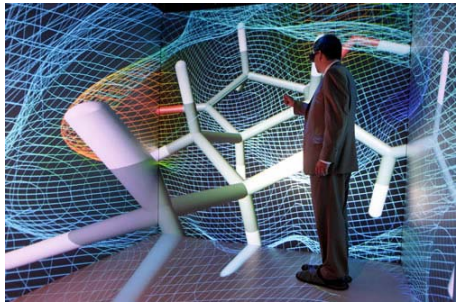
- Computer Graphics has revolutionized medicine
  - Diagnosis and surgical planning
  - Better understanding of many diseases
  - Treatment planning (radiation therapy for cancer)
  - Computer assisted surgery improves surgical outcomes
- Medical Imaging has revolutionized Computer Graphics
  - New algorithms with higher precision and correctness
  - Emergence of Direct Volume Rendering
- Research in Medical Imaging means saving lives and improving life quality!

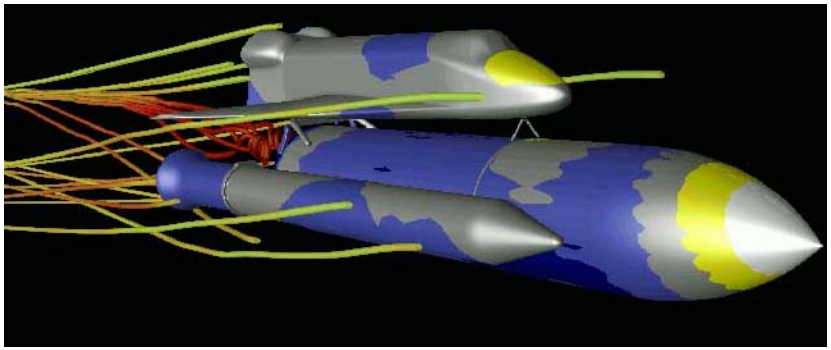


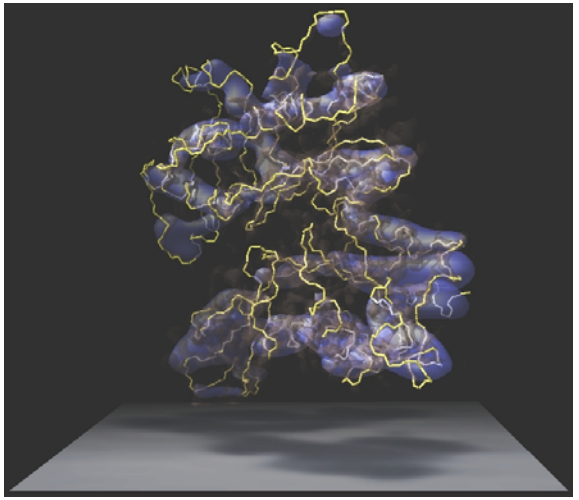
Scientific Visualization

- Scientific measurements (e.g. satellite and geological data) and simulations produce huge data sets.
- Analysing, understanding and communicating this data is improved by displaying it as images.
- Has driven Computer Graphics research in
  - Out-of-core rendering
  - Rendering very large data sets
  - Virtual Reality
  - Innovative interfaces



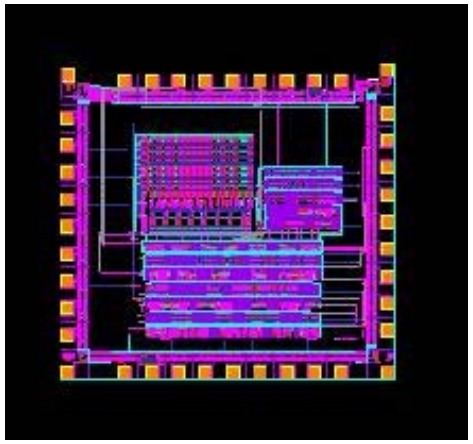


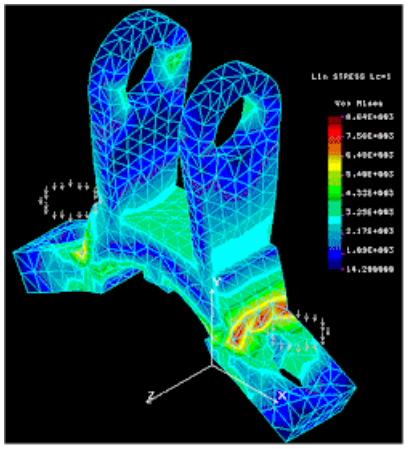




Computer-Aided Design

- Today most mechanical and electrical products are almost entirely designed on the computer
- Computer-aided design and simulation speed up development cycles, reduce costs and result in better products

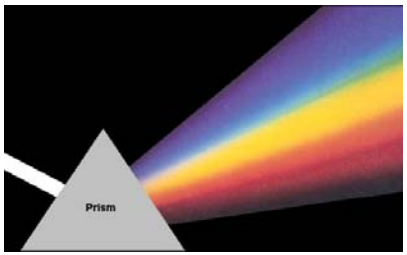


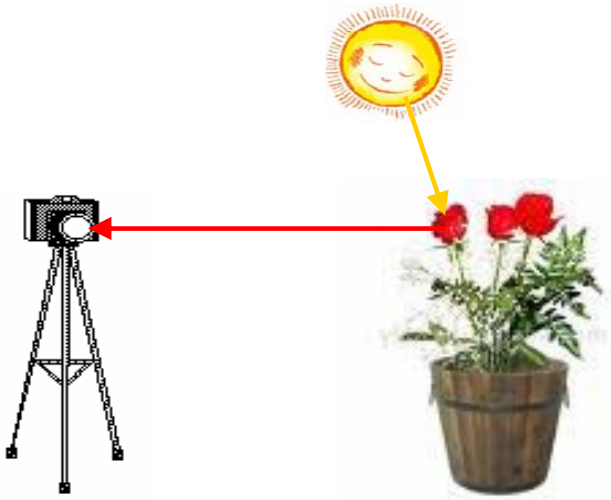


1.3 How to get a picture onto the screen

Elements of image formation

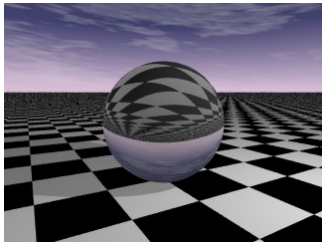
- Objects
- Light sources
- Viewer (camera)





- Attributes that determine how light interacts with the scene (material parameters, atmospheric effects, …)

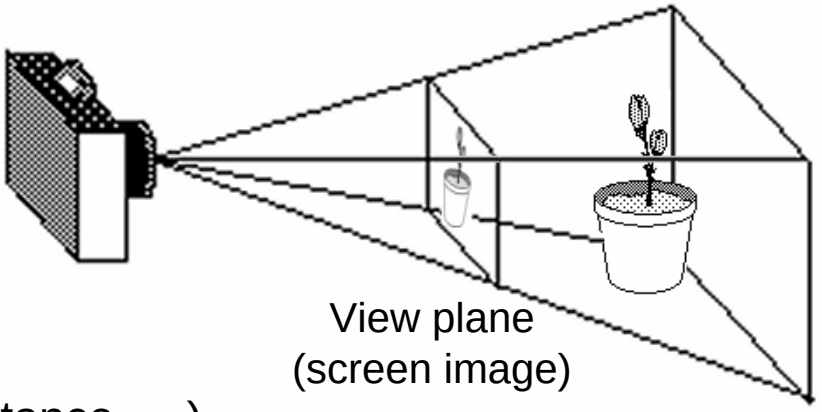




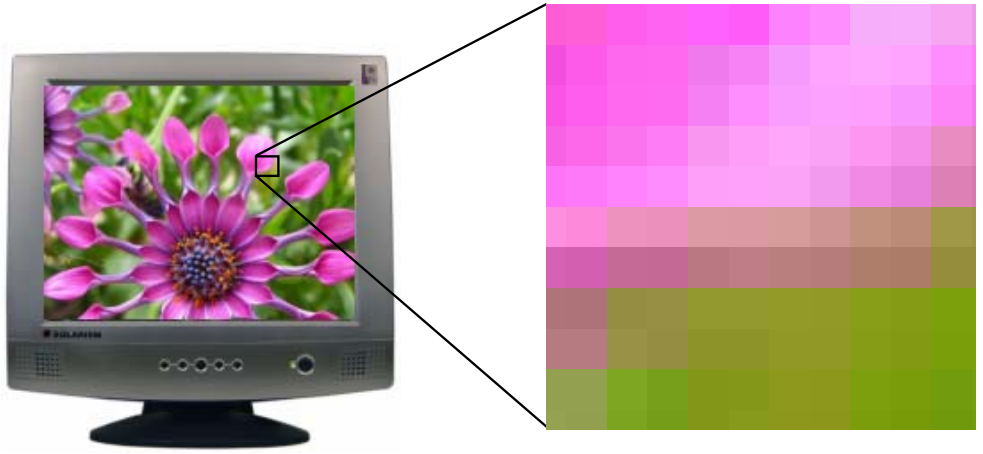
How to get a picture onto the screen (cont'd)

The Synthetic Camera Model

- View point
- View direction
- View orientation
- (projection, field of view, focal distance, …)

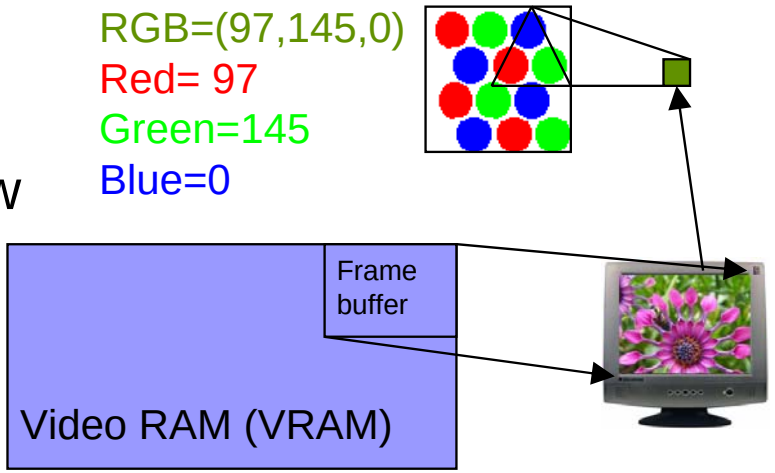


In raster graphics the screen image consists of pixels (picture elements). Hence in order to render an image we have to compute the colour of each pixel representing a part of the scene.

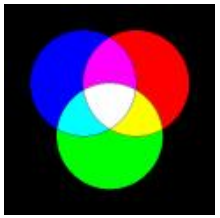


How to get a picture onto the screen (cont'd)

- Image stored as a 2D array of *pixels* (frame buffer = image buffer)
- Scanned out of frame buffer row by row
- Examples
  - CRT/LCD monitor
  - Hardcopy devices (e.g. laser printer)

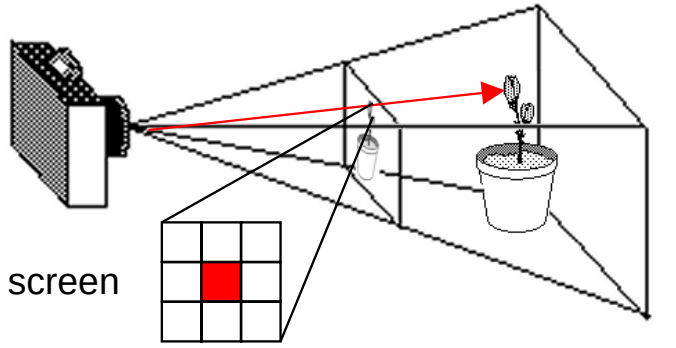


- For colour monitors we usually have 24-bit colour information for each pixel (8-bit Red (R), Green (G) and Blue (B) [RGB value]).
  - (0,0,0) = Black
  - (255,255,0) = Yellow
  - (255,255,255) = White

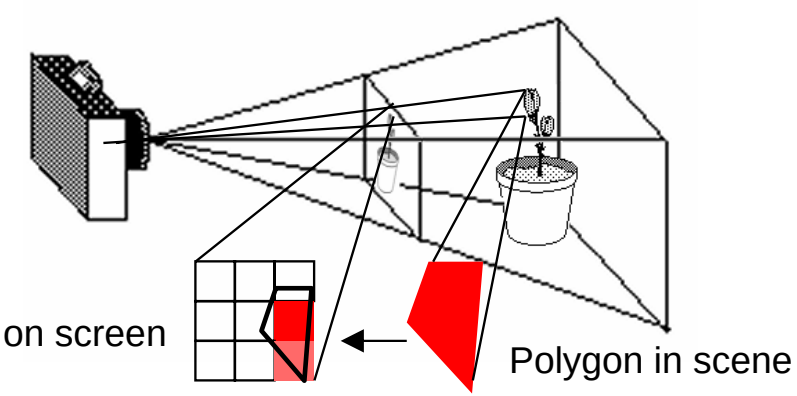


How to get a picture onto the screen (cont'd)

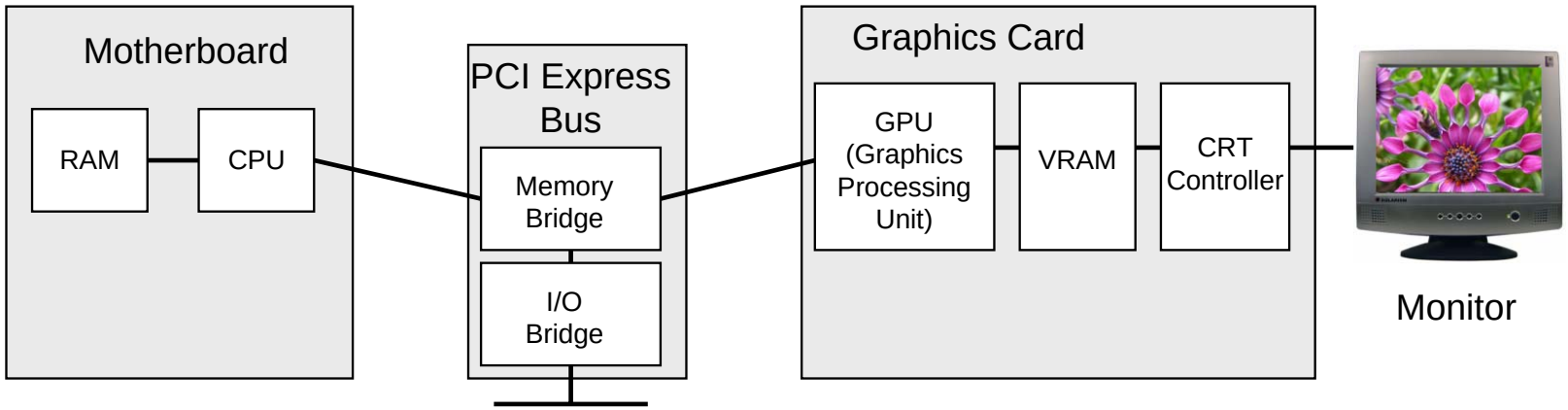
- Raytracing: Trace rays from viewpoint through pixels on the screen into the scene ⇨ high quality but slow



- Polygon rendering: Project polygons representing objects in the scene onto the view plane and render pixels covered by the projected objects ⇨ fast with graphics hardware

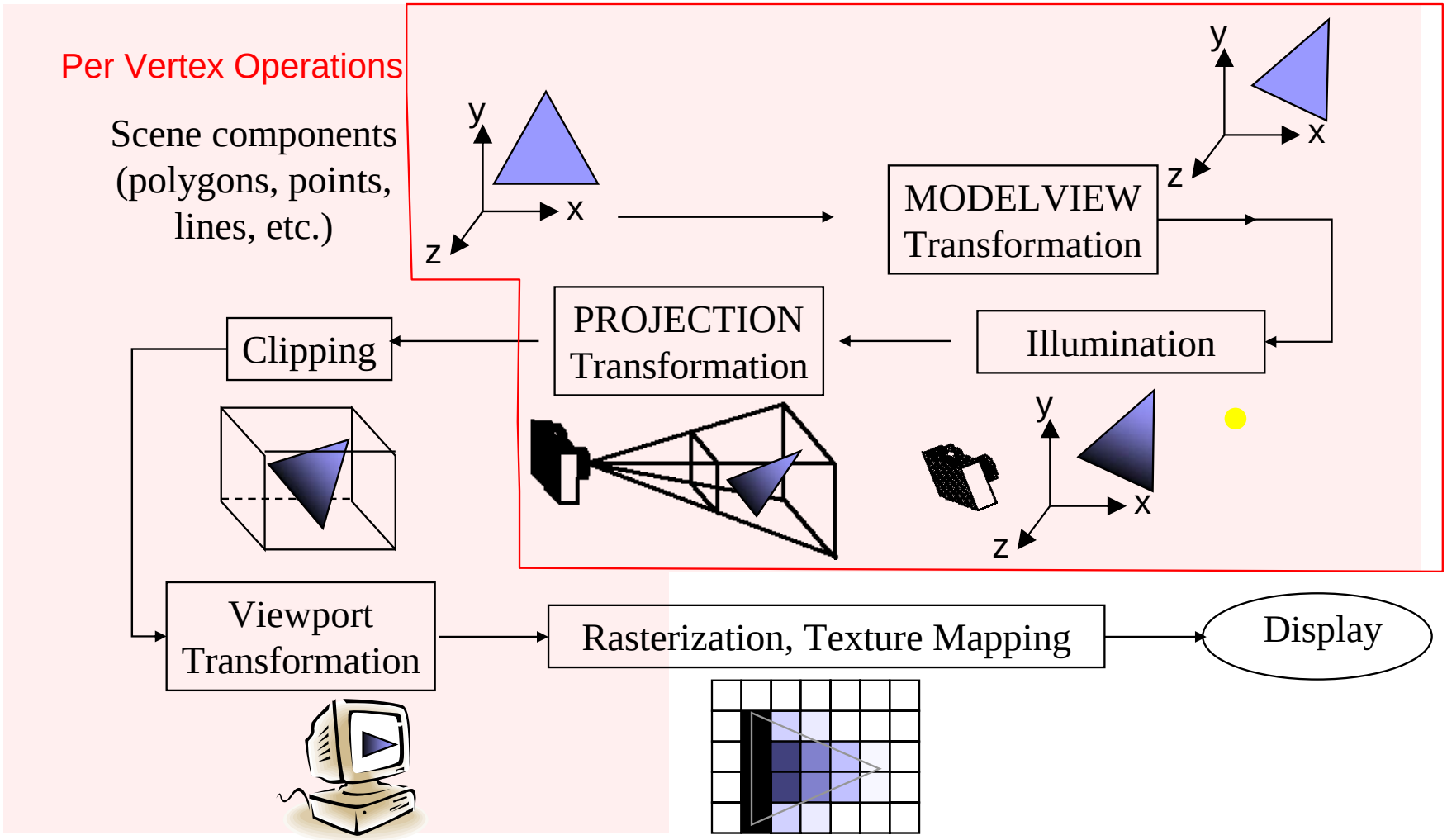


1.4 PC Graphics Hardware



- Many different video cards from many different suppliers
- The main bottleneck is to transfer data from the CPU to the GPU
  - Do as many computations as possible on the GPU
  - Can use hardware shading languages to program the GPU (Cg, GLSL, Sh)

The Graphics Pipeline (simplified)



The actual pipeline

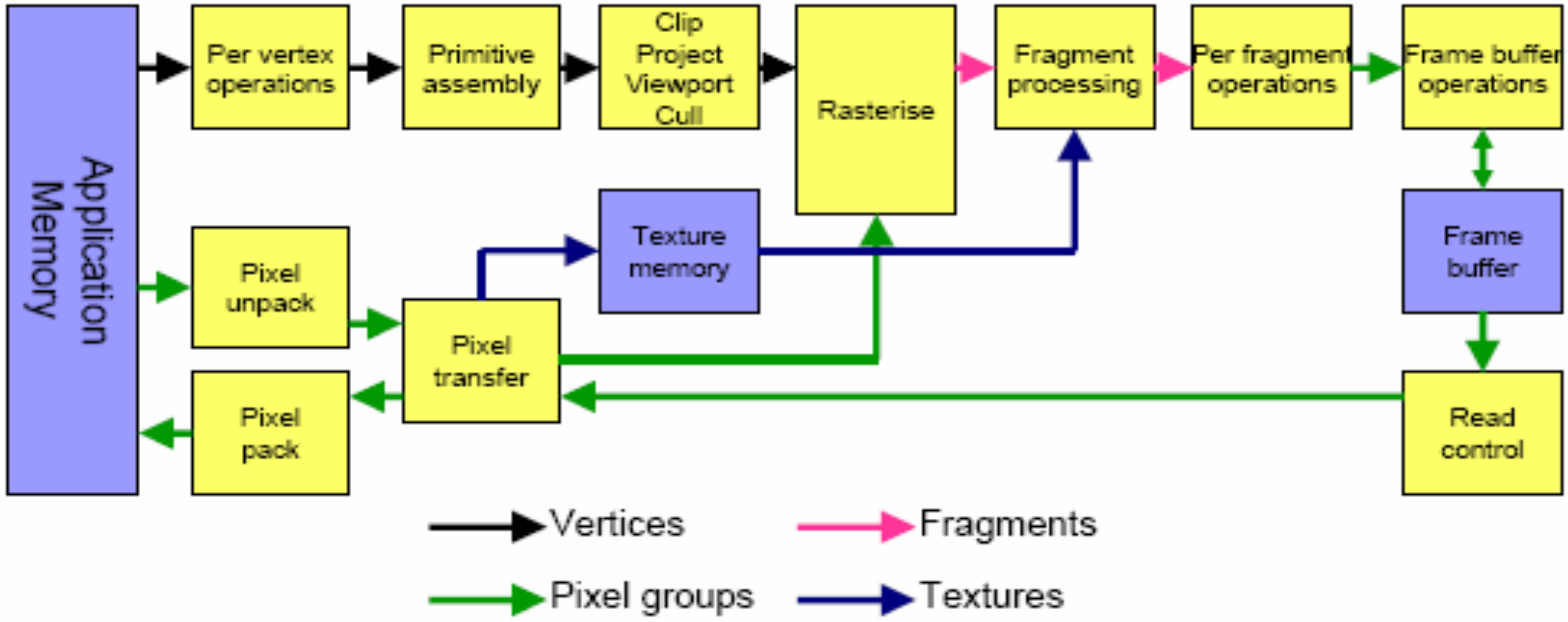
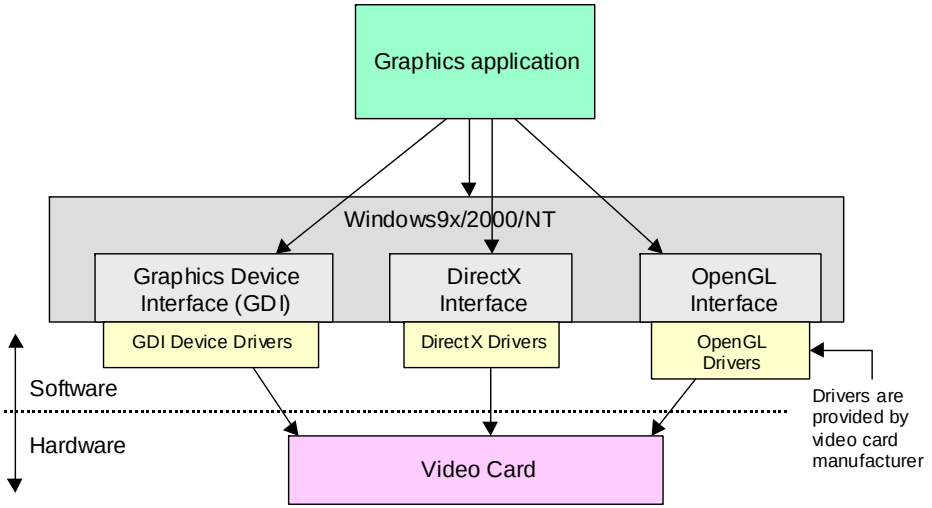


Diagram from OpenGL 1.5 spec

1.5 PC Graphics – Logical Organization

- *GDI* (Graphics Device Interface) provides API to draw lines, curves, polygons etc
  - Included by <windows.h>
- Games use a different interface (*DirectX* or *OpenGL*) to get high-speed full-screen access to VRAM



- *DirectX* = *DirectDraw* + *Direct3D* + *DirectSound* + *DirectInput* + higher-level stuff
  - Microsoft OS's only
- *OpenGL* is an open 3D graphics API
  - Built into MacOS, Windows, Linux
  - Available for most other platforms

We're using OpenGL throughout this paper