Lecture 1

Computer Graphics and Systems

What is Computer Graphics ?

- Image Formation

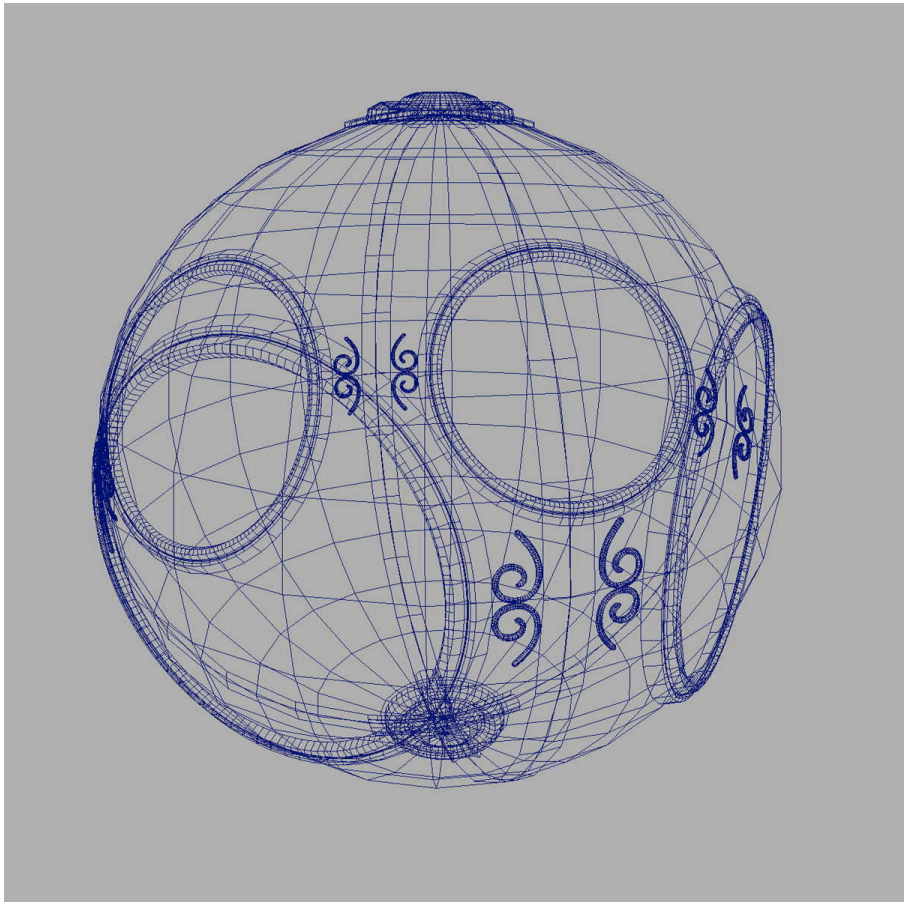
Sun Object

Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Computer Graphics 1960 - 70

- Wireframe Graphics

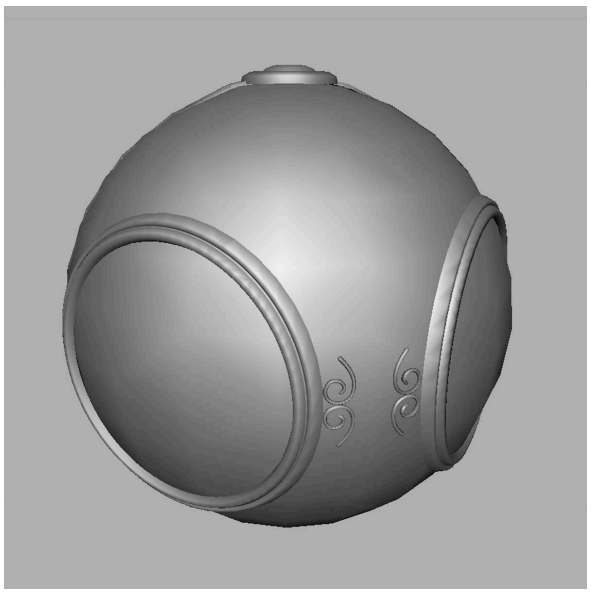
Sketchpad - an early CG system



wireframe representation of sun object

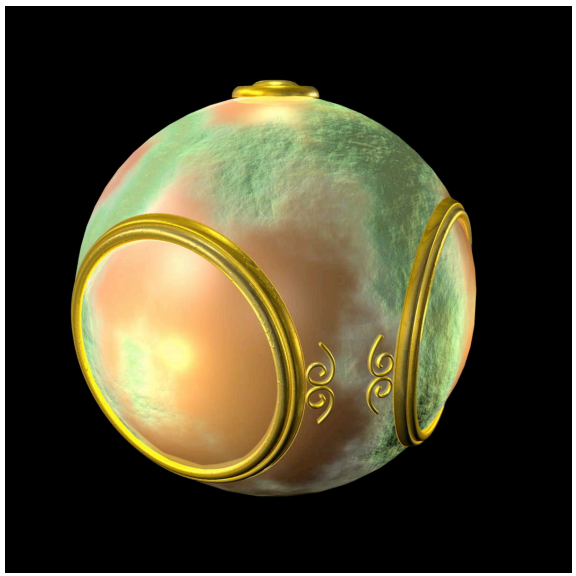
Computer Graphics 1980 - 90

Realism comes to computer graphics



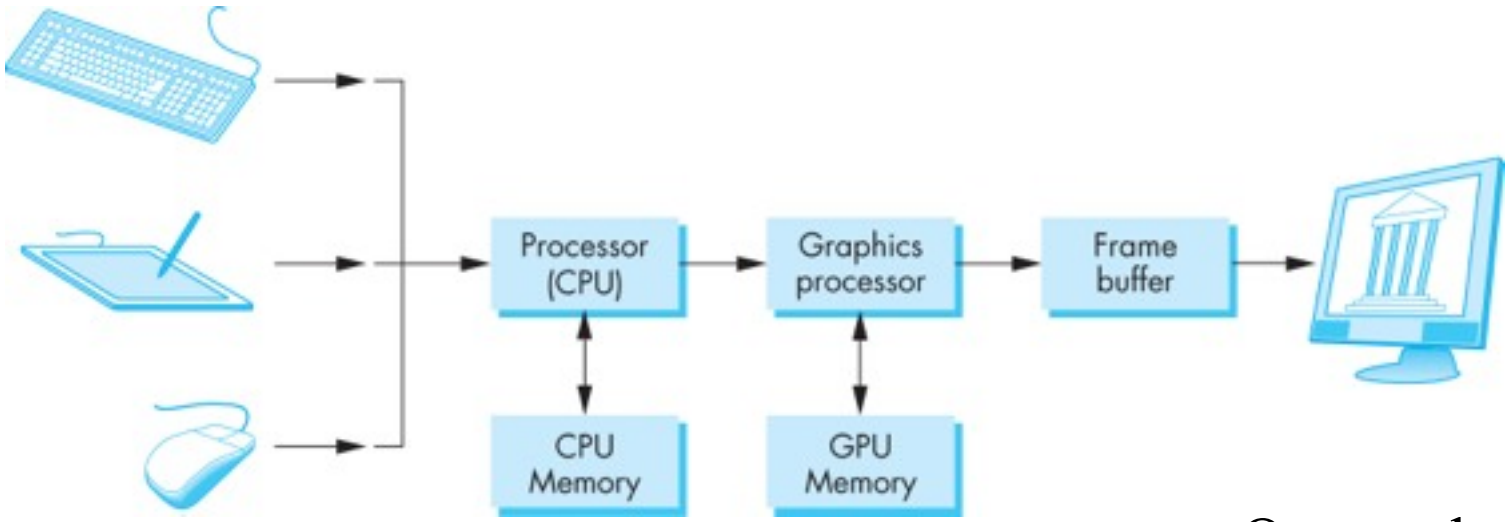
smooth shading

environment mapping



bump mapping

Basic Graphics System



Input devices

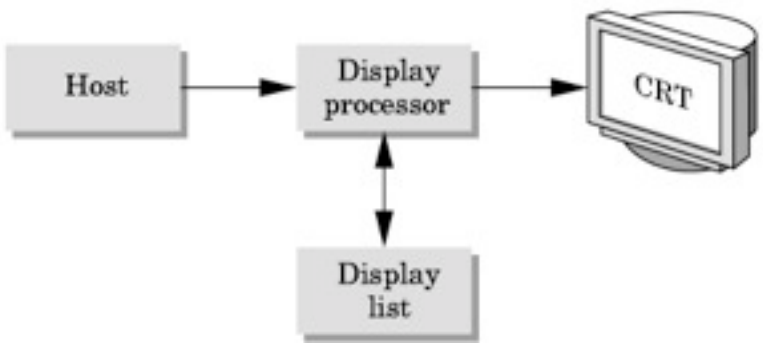
Output device

Image formed in frame buffer

Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Display Processor

- Rather than have the host computer try to refresh display use a special purpose computer called a *display processor* (DPU)

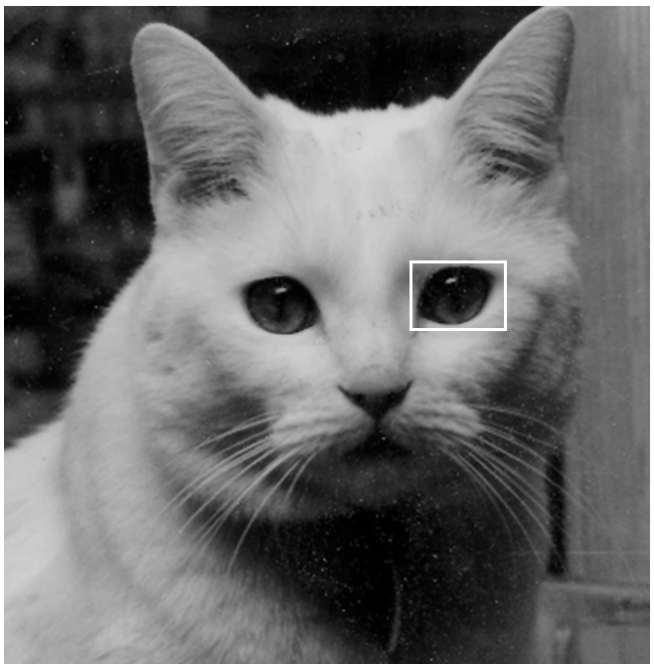


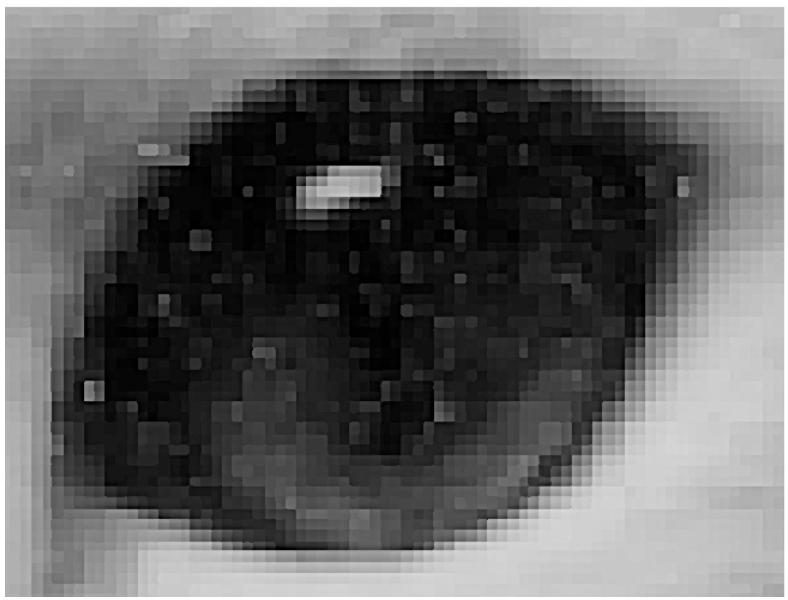
- Graphics stored in display list (display file) on display processor
- Host *compiles* display list and sends to DPU

Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Raster Graphics

- Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*





Digital Graphics + Visual Acuity

- Allows us to go from lines and wire frame images to filled polygons

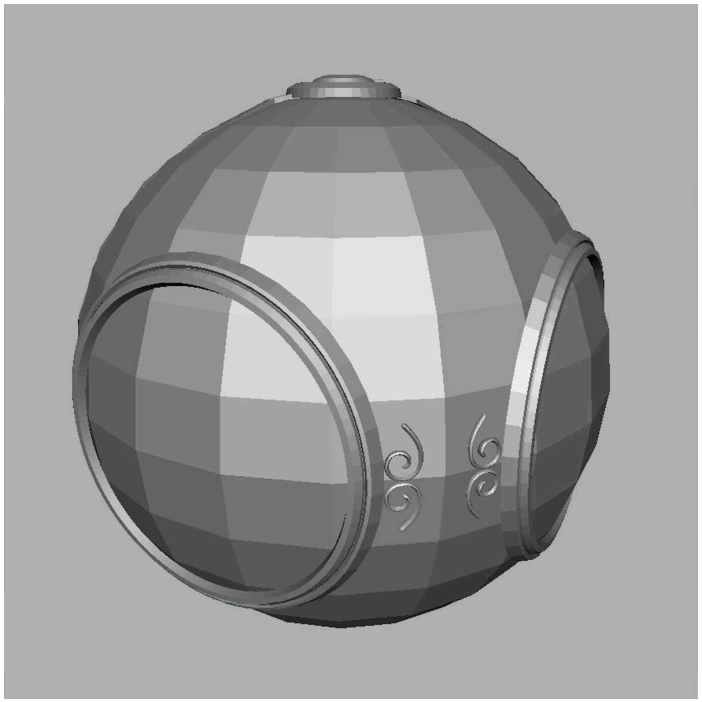


Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Computer Graphics 2000 ++

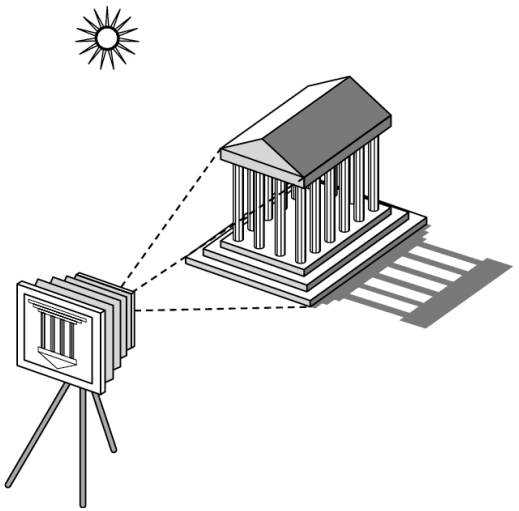
- Photorealism with Interactivity
- Graphics cards for PCs dominate market
  - Nvidia, ATI (part of AMD)
- Game boxes and game players determine direction of market
- Computer graphics routine in movie industry: Maya, Lightwave
- Programmable graphics pipelines

Image Formation

- In computer graphics, we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system

Elements of Image Formation

- Objects
- Viewer
- Light source(s)



- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, the viewer, and the light source(s)

Light

- *Light* is the part of the electromagnetic spectrum that causes a reaction in our visual systems
- Generally these are wavelengths in the range of about 350-750 nm (nanometers)
- Long wavelengths appear as reds and short wavelengths as blues

Ray Tracing & Image Formation

One way to form an image is to follow rays of light from a point source finding which rays enter the lens of the camera. However, each ray of light may have multiple interactions with objects before being absorbed or going to infinity.

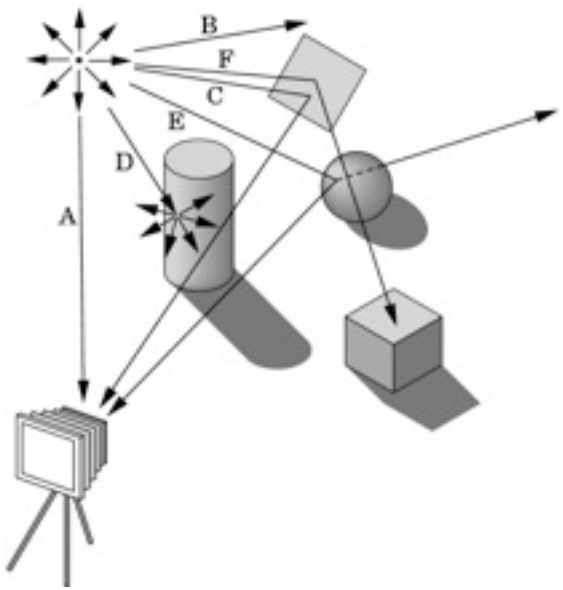


Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Local vs Global Illumination

- Cannot compute color or shade of each object independently
  - Some objects are blocked from light
  - Light can reflect from object to object
  - Some objects might be translucent

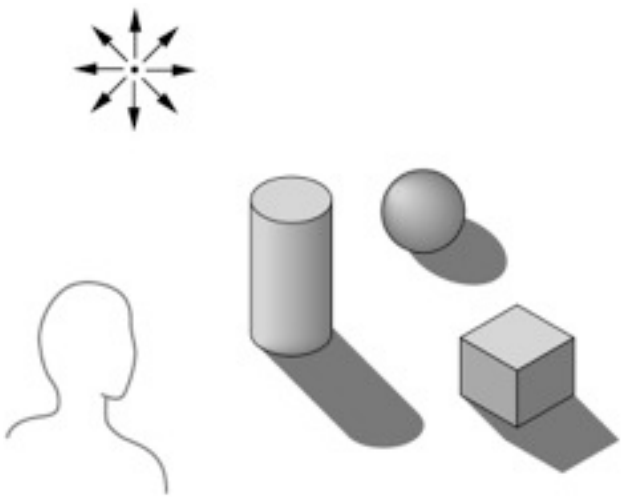


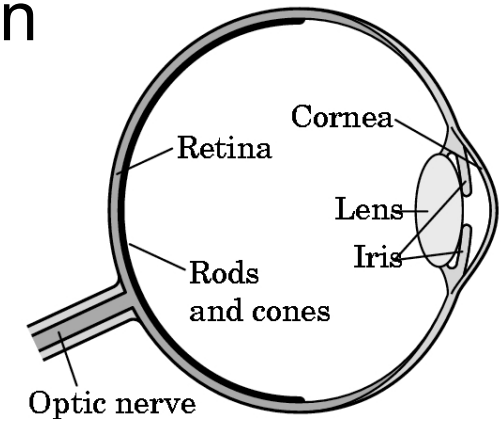
Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Luminance & Color Images

- Luminance Image
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television
- Color Image
  - Has perceptional attributes of hue, saturation, and lightness
  - Do we have to match every frequency in visible spectrum? No!

Three Color Theory

- Human visual system has two types of sensors
  - Rods: monochromatic, night vision
  - Cones
    - Color sensitive
    - Three types of cones
    - Only three values (the *tristimulus* values) are sent to the brain



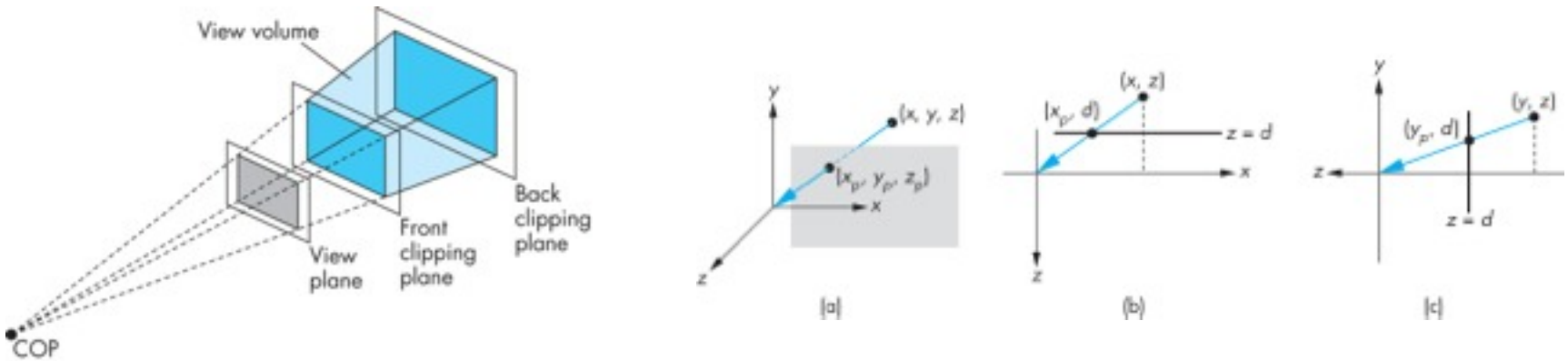
- Need only match these three values
  - Need only three *primary* colors

Figure from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Additive / Subtractive Color

- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, projection systems, positive film
  - Primaries are Red (R), Green (G), Blue (B)
- Subtractive color
  - Form a color by filtering white light with cyan (C), Magenta (M), and Yellow (Y) filters
    - Light-material interactions
    - Printing
    - Negative film

Perspective Camera



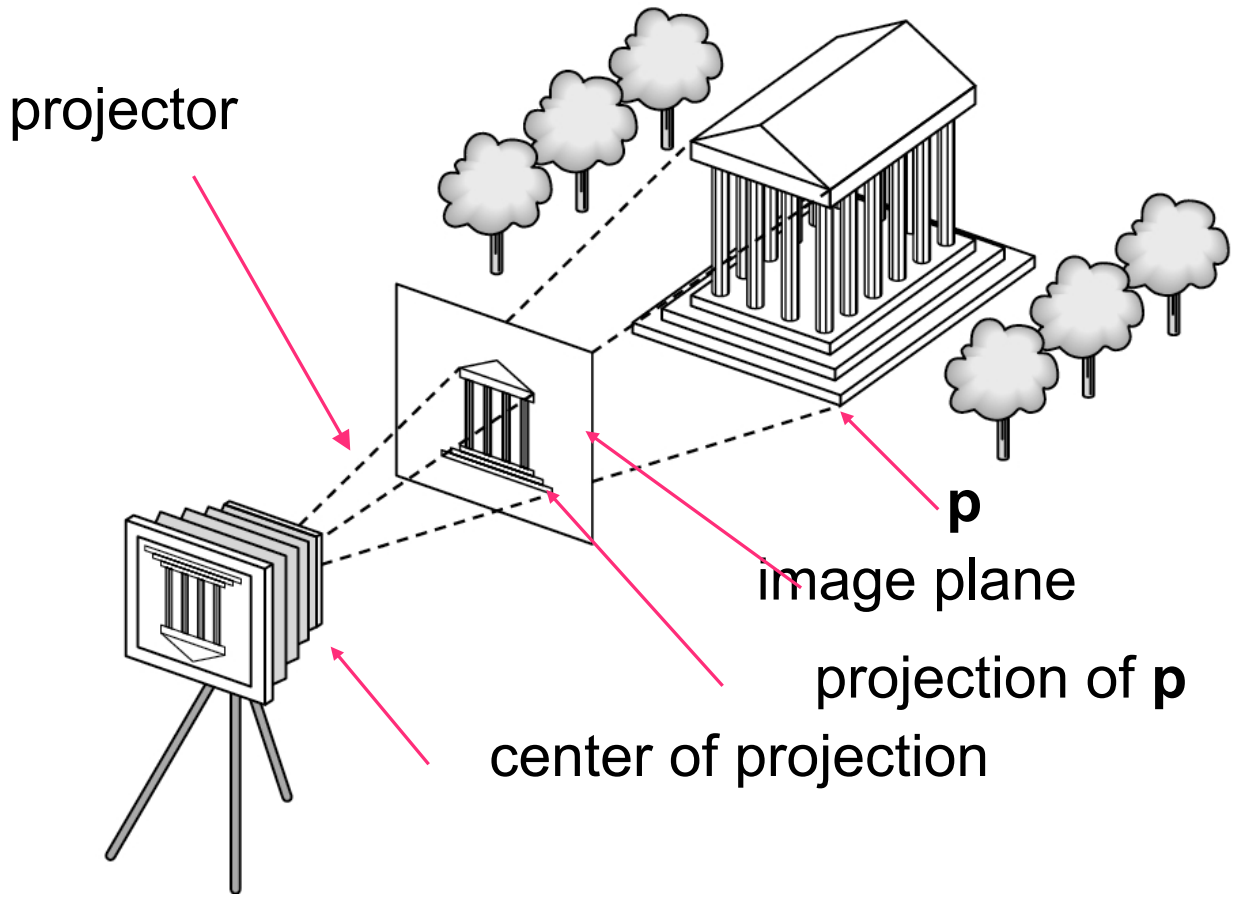
Use trigonometry to find projection of point at (x,y,z)

$$x_p = -x/z/d \qquad y_p = -y/z/d \qquad z_p = d$$

These are equations of simple perspective

Figures from *Ed Angel,D.Shreiner: Interactive Computer Graphics, 6th Ed., 2012 © Addison Wesley*

Virtual Camera Model



What will you learn in this course ?

- An introduction to Interactive Computer Graphics
  - Software
  - Applications
- Top-down approach
- Shader-Based OpenGL compatible with
  - OpenGL 3.1 (and later)
  - Open GL ES 2.0 (iPhone/MacOSx)
  - webGL (intro)

Pre-requisites

- Good programming skills in C++
- Basic Data Structures
  - Linked lists
  - Arrays
- Geometry
- Simple Linear Algebra

Resources

- Can run OpenGL on any system
  - Windows: check graphics card properties for level of OpenGL supported
  - Linux
  - Mac: need extensions for 3.1 equivalence
- Get GLUT from web if needed
  - Provided on Macs
  - freeglut available on web
- Get GLEW from web
- WebGL: most newer browsers

References

- www.opengl.org
  - Standards documents
  - Sample code
- The OpenGL Programmer's Guide (the Redbook) 7th Edition
  - The definitive reference
  - Mixes 3.0 and 3.1
- OpenGL Shading Language, 3rd Edition
- OpenGL ES 2.0 Programming Guide

Lectures & Text Book Organization

Part I : Jan -> Feb (upto midterm I)

1.Chapter 1 (Intro)

- What is Computer Graphics?
- Applications Areas
- History
- Image formation
- Basic Architecture

2. Chapter 2 (Basic OpenGL)

- Architecture
- GLUT
- Simple programs in two and three dimensions
- Basic shaders and GLSL
- Interaction

3.Chapters 3-5 (3D Graphics)

- Geometry
- Transformations
- Homogeneous Coordinates
- Viewing

4.Chapter 10 (Curves and Surfaces)

5. Extra Material !

- Quaternions (chap 3)
- A-splines/B-splines (implicit vs parametric)
- Fractals & L-systems (Turtle geometry) (chap 9)

Lectures & Text Book Organization

Part II : March -> mid April (upto midterm II)

6. Chapter 5 (Illumination)

- Display, Color
- Lighting & Shading

7. Chapter 7,11 (Per-Pixel)

- Buffers
- Texture Mapping
- Shader Applications
- Compositing and Transparency
- Bump Mapping
- Global Illumination (Radiosity)

8. Extra Material !

- Sampling and Anti-Aliasing
- Reflection, Refraction, Shadows (Ray Tracing)

Lectures & Text Book Organization

Part III : mid April -> end (upto Final)

9. Chapter 6, 8
(Polygon Visibility)
- Depth Sort, Painter's
- BSP Trees

10. Extra Material !
- Particle Systems (Chap 9)
- Fast Neighborhood Data Structures
- Physically Based Animation