Introduction to Computer Graphics with WebGL

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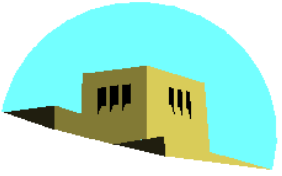
Founding Director, Arts, Research, Technology and Science Laboratory

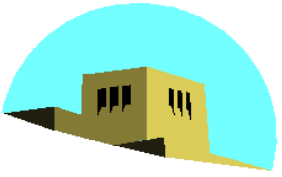University of New Mexico

Models and Architectures

Objectives

- Learn the basic design of a graphics system

- Introduce pipeline architecture

- Examine software components for an interactive graphics system
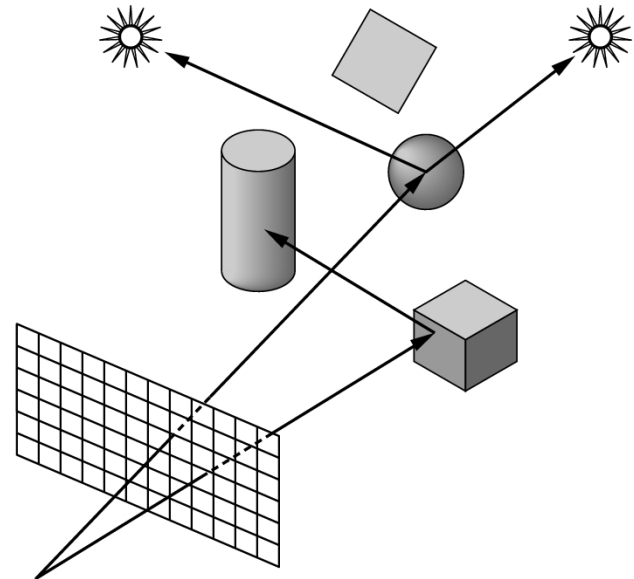
Image Formation Revisited

- Can we mimic the synthetic camera model to design graphics hardware software?

- Application Programmer Interface (API)
  - Need only specify
    - Objects
    - Materials
    - Viewer
    - Lights

- But how is the API implemented?

Physical Approaches

- **Ray tracing**: follow rays of light from center of projection until they either are absorbed by objects or go off to infinity
  - Can handle global effects
    - Multiple reflections
    - Translucent objects
  - Slow
  - Must have whole data base available at all times

- **Radiosity**: Energy based approach
  - Very slow

Practical Approach

- Process objects one at a time in the order they are generated by the application
  - Can consider only local lighting
- Pipeline architecture

Vertices → | Vertex Processor | → | Clipper and Primitive Assembler | → | Rasterizer | → | Fragment Processor | → Pixels

application program

display

- All steps can be implemented in hardware on the graphics card

Vertex Processing

- Much of the work in the pipeline is in converting object representations from one coordinate system to another
  - Object coordinates
  - Camera (eye) coordinates
  - Screen coordinates

- Every change of coordinates is equivalent to a matrix transformation

- Vertex processor also computes vertex colors

Vertices → Vertex Processor → Clipper and Primitive Assembler → Rasterizer → Fragment Processor → Pixels

Projection

- *Projection* is the process that combines the 3D viewer with the 3D objects to produce the 2D image
  - Perspective projections: all projectors meet at the center of projection
  - Parallel projection: projectors are parallel, center of projection is replaced by a direction of projection

Vertices → Vertex Processor → Clipper and Primitive Assembler → Rasterizer → Fragment Processor → Pixels

Primitive Assembly

Vertices must be collected into geometric objects before clipping and rasterization can take place

- Line segments

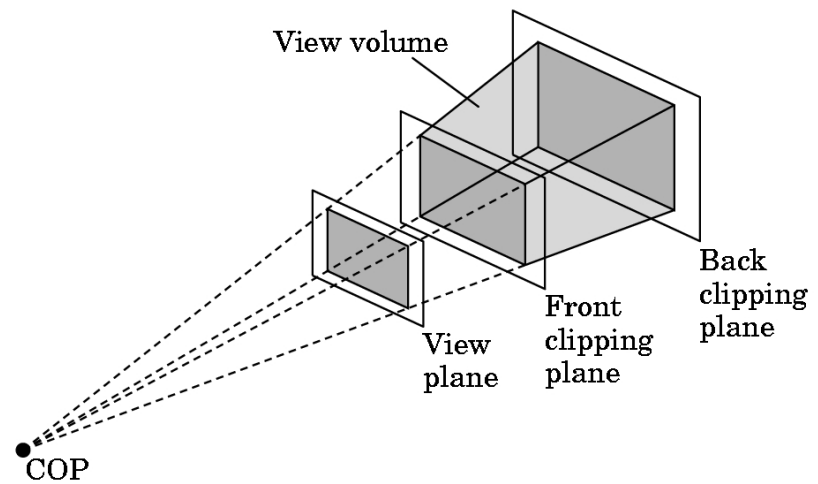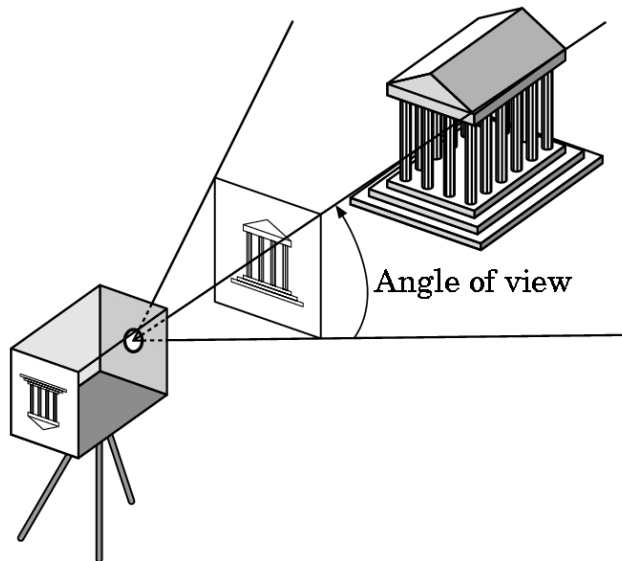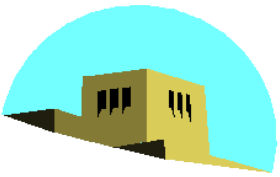- Polygons

- Curves and surfaces

Vertices ➤ Vertex Processor ➤ Clipper and Primitive Assembler ➤ Rasterizer ➤ Fragment Processor ➤ Pixels
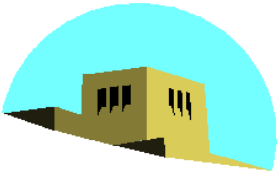
Clipping

Just as a real camera cannot "see" the whole world, the virtual camera can only see part of the world or object space

- Objects that are not within this volume are said to be *clipped* out of the scene

Rasterization

- If an object is not clipped out, the appropriate pixels in the frame buffer must be assigned colors

- Rasterizer produces a set of fragments for each object

- Fragments are "potential pixels"
  - Have a location in frame bufffer
  - Color and depth attributes

- Vertex attributes are interpolated over objects by the rasterizer

Vertices → Vertex Processor → Clipper and Primitive Assembler → Rasterizer → Fragment Processor → Pixels

Fragment Processing

- Fragments are processed to determine the color of the corresponding pixel in the frame buffer

- Colors can be determined by texture mapping or interpolation of vertex colors

- Fragments may be blocked by other fragments closer to the camera
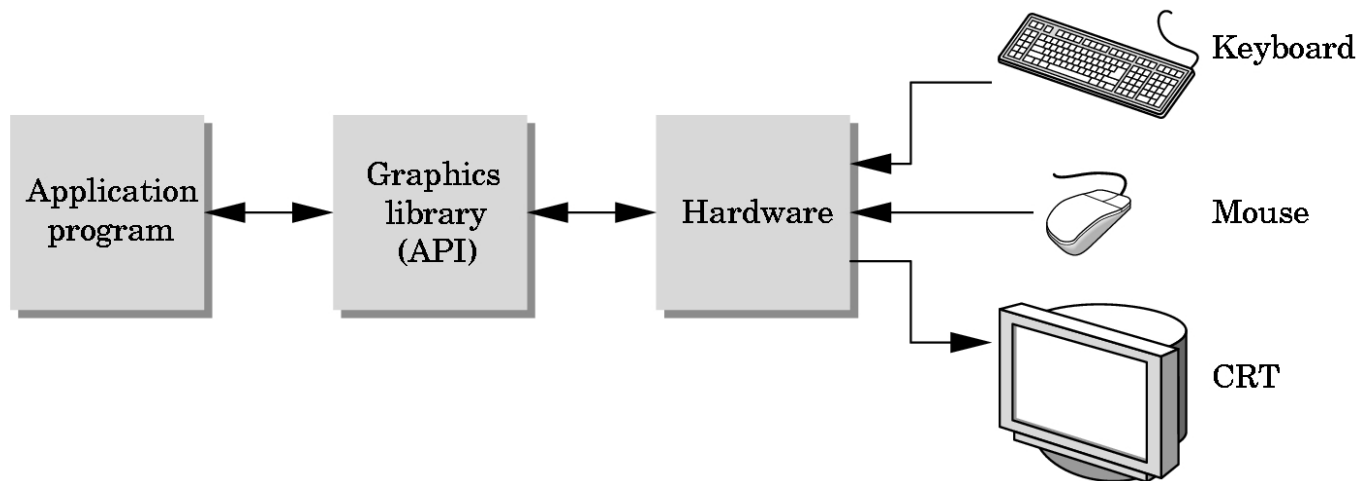
  - Hidden-surface removal

Vertices → Vertex Processor → Clipper and Primitive Assembler → Rasterizer → Fragment Processor → Pixels

Angel and Shreiner: Interactive Computer Graphics 7E © Addison-Wesley 2015

The Programmer's Interface

- Programmer sees the graphics system through a software interface: the Application Programmer Interface (API)

API Contents

- Functions that specify what we need to form an image
  - Objects
  - Viewer
  - Light Source(s)
  - Materials
- Other information
  - Input from devices such as mouse and keyboard
  - Capabilities of system

Object Specification

- Most APIs support a limited set of primitives including
  - Points (0D object)
  - Line segments (1D objects)
  - Polygons (2D objects)
  - Some curves and surfaces
    - Quadrics
    - Parametric polynomials
- All are defined through locations in space or *vertices*
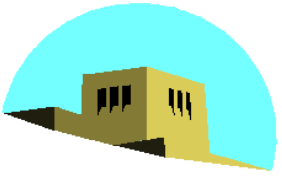
Example (old style)

type of object

location of vertex

```
glBegin(GL_POLYGON)
  glVertex3f(0.0, 0.0, 0.0);
  glVertex3f(0.0, 1.0, 0.0);
  glVertex3f(0.0, 0.0, 1.0);
glEnd( );
```
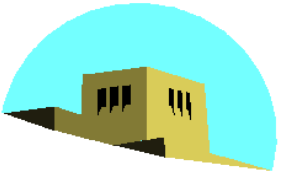
end of object definition

Example (GPU based)

- Put geometric data in an array

```
var points = [
  vec3(0.0, 0.0, 0.0),
  vec3(0.0, 1.0, 0.0),
  vec3(0.0, 0.0, 1.0),
];
```
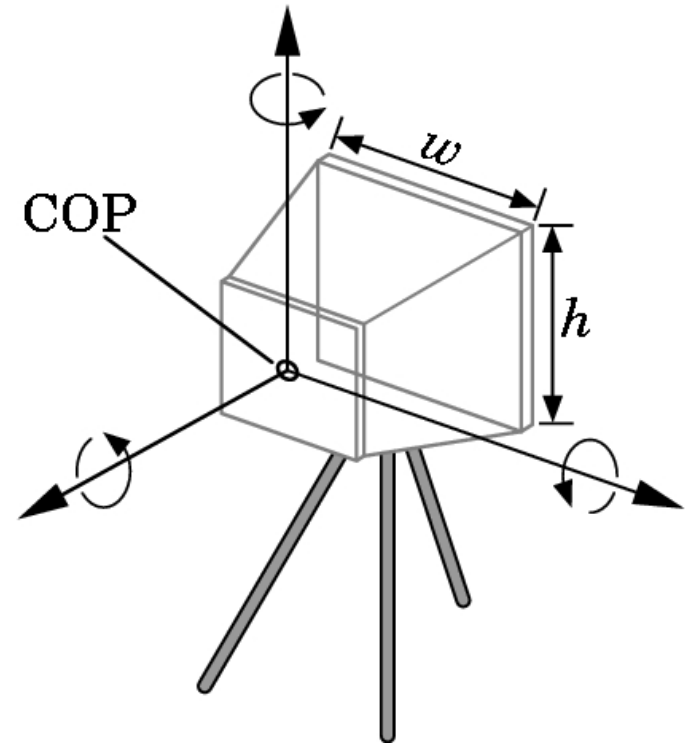
- Send array to GPU
- Tell GPU to render as triangle

Camera Specification

- Six degrees of freedom
  - Position of center of lens
  - Orientation
- Lens
- Film size
- Orientation of film plane

Lights and Materials

- Types of lights
  - Point sources vs distributed sources
  - Spot lights
  - Near and far sources
  - Color properties
- Material properties
  - Absorption: color properties
  - Scattering
    - Diffuse
    - Specular