Models and Architectures

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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

  application program

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

  display
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
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

![Diagram of rendering pipeline](image-url)
Primitive Assembly

Vertices must be collected into geometric objects before clipping and rasterization can take place
- Line segments
- Polygons
- Curves and surfaces
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 buffer
  - Color and depth attributes
• Vertex attributes are interpolated over objects by the rasterizer.
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
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

```c
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();
```

- type of object
- location of vertex
- end of object definition
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