Classifying Graphics by Rendering Speed

- How long to generate an image
- Image frames may be precomputed and displayed at a different rate later
Realistic

• Take as long as necessary
• Often only rendering one frame

Production/Movies

• Limited by production schedule
• Display 24-60 frames per second
Interactive

• Application & rendering at display speed

Frame Rate

• New image how often?
  – Slow: seconds per frame
  – Fast: frames per second

• Some rates:
  – 1-2 sec/frame: barely able to interact
  – 12 fps: start to fuse motion
  – 24 fps: film
  – 30-60 fps: TV
  – up to ~100 fps: computer display
Rendering vs. Display

Frame Rate

- *Latency*: time between action and result of that action
- Render slower than display rate
  - Prediction or long latency
  - Double buffer; double / triple frame
    - Ghosting
  - Pipeline
- Render much faster than display
  - Latency < frame time
  - Common in games

Anatomy of an Interactive Application

```
setup
do {
  render frame
  read input
  update state
}
```
Event Loop

- More sophisticated application setup
  
  ```
  do {
    wait for event
    while (events in queue)
      process event
  } until done
  ```

Why Events?

- Receive and queue events asynchronously
- Event callback
  - User code called to respond to event
- Event response can queue new events
  - Including a *Render event*: not every event requires re-rendering
- Similar model used by windowing systems
Some Common Events

- From GLUT
  - Display
  - Key press
  - Mouse button, mouse motion
  - Menu, mouse enter/leave window
  - Reshape window, window visibility change
  - Idle

What About Rendering?

- Same models, rerendered every frame with minor changes
- Persistent data structure for scene
  - Other events modify data structure
  - Display event renders as it exists now
Scene Graph

- Tree / DAG representation of scene
  - Interior nodes
    - transforms, appearance
  - Leaf nodes
    - geometry

Scene Graph Details

- Each node has
  - Node type
  - Children
  - Auxiliary node-type specific data
- Find locations by name or pointer
  - Update data
  - Rewrite sections of graph
Scene Graph Rendering

- Traverse Graph
- Display actions
  - 1–handful GL calls
- Options
  - action does traversal
  - pre & post actions
  - SG state management

Scene Graph Traversal

- Not just for rendering
- Save
  - Rather than render, print to file
- Optimize
  - Sort by state changes
  - Sort by distance for transparency
- Produce intermediate *display list*
Scene Graph Layout

• All about the coordinate spaces
  – World
  – Room
  – UserN
    • Leg, Arm, Head, …
  – Lights
  – …