Better Interactive Programs

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Objectives

- Learn to build more sophisticated interactive programs using
  - Picking
    - Select objects from the display
    - Three methods
  - Rubberbanding
    - Interactive drawing of lines and rectangles
  - Display Lists
    - Retained mode graphics

Picking

- Identify a user-defined object on the display
- In principle, it should be simple because the mouse gives the position and we should be able to determine to which object(s) a position corresponds
- Practical difficulties
  - Pipeline architecture is feed forward, hard to go from screen back to world
  - Complicated by screen being 2D, world is 3D
  - How close do we have to come to object to say we selected it?

Three Approaches

- Hit list
  - Most general approach but most difficult to implement
- Use back or some other buffer to store object ids as the objects are rendered
- Rectangular maps
  - Easy to implement for many applications
  - See paint program in text

Rendering Modes

- OpenGL can render in one of three modes selected by **`glRenderMode(mode)`**
  - **`GL_RENDER`**: normal rendering to the frame buffer (default)
  - **`GL_FEEDBACK`**: provides list of primitives rendered but no output to the frame buffer
  - **`GL_SELECTION`**: Each primitive in the view volume generates a *hit record* that is placed in a *name stack* which can be examined later

Selection Mode Functions

- `glSelectBuffer()`: specifies name buffer
- `glInitNames()`: initializes name buffer
- `glPushName(id)`: push id on name buffer
- `glPopName()`: pop top of name buffer
- `glLoadName(id)`: replace top name on buffer

- id is set by application program to identify objects

Using Selection Mode

- Initialize name buffer
- Enter selection mode (using mouse)
- Render scene with user-defined identifiers
- Reenter normal render mode
  This operation returns number of hits
- Examine contents of name buffer (hit records)
  Hit records include id and depth information

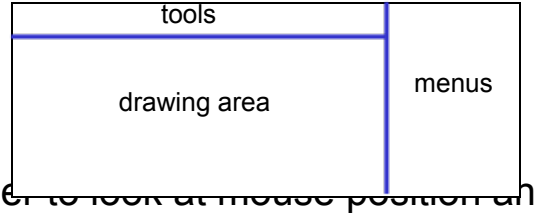
Selection Mode and Picking

- As we just described it, selection mode won't work for picking because every primitive in the view volume will generate a hit
- Change the viewing parameters so that only those primitives near the cursor are in the altered view volume

  Use **`gluPickMatrix`** (see text for details)

Using Regions of the Screen

- Many applications use a simple rectangular arrangement of the screen
  Example: paint/CAD program

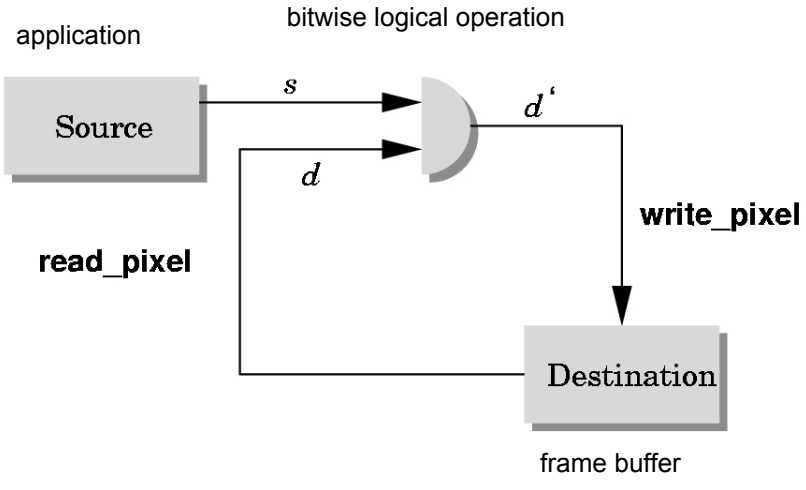


- Easier to look at mouse position and determine which area of screen it is in than using selection mode picking

Using another buffer and colors for picking

- For a small number of objects, we can assign a unique color (often in color index mode) to each object
- We then render the scene to a color buffer other than the front buffer so the results of the rendering are not visible
- We then get the mouse position and use `glReadPixels()` to read the color in the buffer we just wrote at the position of the mouse
- The returned color gives the id of the object

Writing Modes



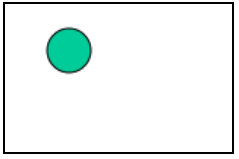
XOR write

- Usual (default) mode: source replaces destination (d' = s)
  - Cannot write temporary lines this way because we cannot recover what was "under" the line in a fast simple way
- Exclusive OR mode (XOR) (d' = d ⊕ s)
  - x ⊕ y ⊕ x =y
  - Hence, if we use XOR mode to write a line, we can draw it a second time and line is erased!

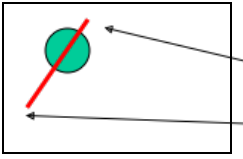
Rubberbanding

- Switch to XOR write mode
- Draw object
  - For line can use first mouse click to fix one endpoint and then use motion callback to continuously update the second endpoint
  - Each time mouse is moved, redraw line which erases it and then draw line from fixed first position to to new second position
  - At end, switch back to normal drawing mode and draw line
  - Works for other objects: rectangles, circles

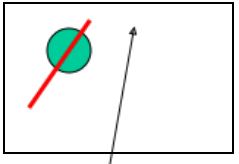
Rubberband Lines



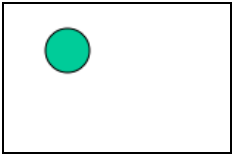
initial display



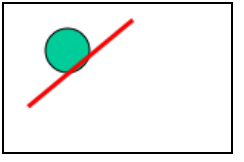
draw line with mouse
in XOR mode



mouse moved to
new position



original line redrawn
with XOR



new line drawn
with XOR

XOR in OpenGL

- There are 16 possible logical operations between two bits
- All are supported by OpenGL
  - Must first enable logical operations
  - `glEnable(GL_COLOR_LOGIC_OP)`
  - Choose logical operation
  - `glLogicOp(GL_XOR)`
  - `glLogicOp(GL_COPY)` (default)

Immediate and Retained Modes

- Recall that in a standard OpenGL program, once an object is rendered there is no memory of it and to redisplay it, we must re-execute the code for it
  - Known as *immediate mode graphics*
  - Can be especially slow if the objects are complex and must be sent over a network
- Alternative is define objects and keep them in some form that can be redisplayed easily
  - *Retained mode graphics*
  - Accomplished in OpenGL via *display lists*

Display Lists

- Conceptually similar to a graphics file
  - Must define (name, create)
  - Add contents
  - Close
- In client-server environment, display list is placed on server
  - Can be redisplayed without sending primitives over network each time

Display List Functions

- Creating a display list

```
GLuint id;

void init()
{
  id = glGenLists( 1 );
  glNewList( id, GL_COMPILE );
  /* other OpenGL routines */
  glEndList();
}
```

- Call a created list

```
void display()
{
  glCallList( id );
}
```

Display Lists and State

- Most OpenGL functions can be put in display lists
- State changes made inside a display list persist after the display list is executed
- Can avoid unexpected results by using **`glPushAttrib`** and **`glPushMatrix`** upon entering a display list and **`glPopAttrib`** and **`glPopMatrix`** before exiting

Hierarchy and Display Lists

- Consider model of a car
  - Create display list for chassis
  - Create display list for wheel

```
glNewList( CAR, GL_COMPILE );
   glCallList( CHASSIS );
   glTranslatef( … );
   glCallList( WHEEL );
   glTranslatef( … );
   glCallList( WHEEL );
        …
glEndList();
```