OpenGL projection, basic viewing and event handling

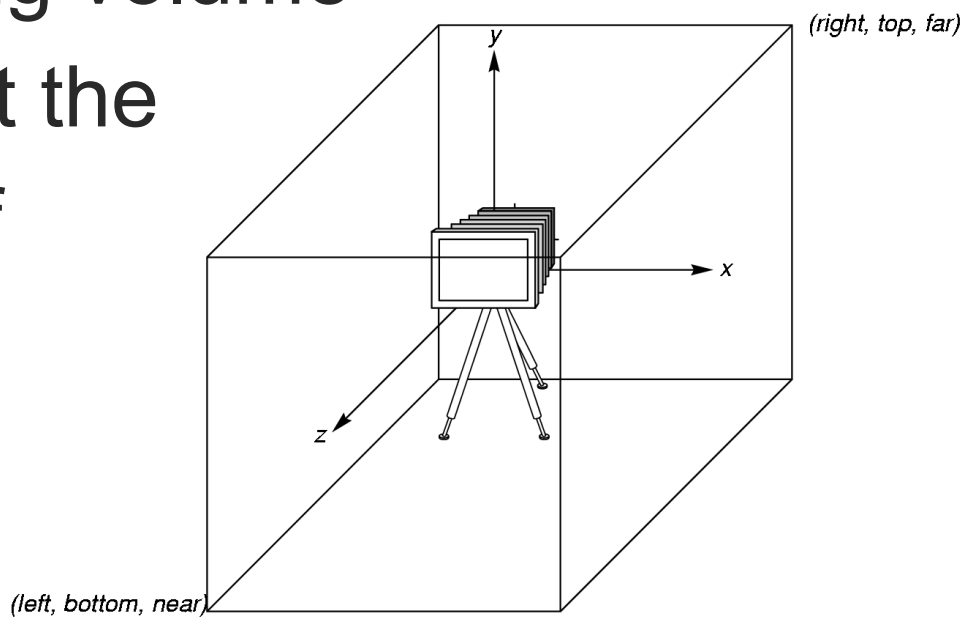
Coordinate Systems

- The units in **`glVertex`** are determined by the application and are called *object coordinates*
- In OpenGL object coordinates are first converted to *world coordinates*
- The viewing specifications are also in object coordinates and it is the size of the viewing volume that determines what will appear in the image
- Internally, OpenGL will convert to *camera coordinates* and later to *screen coordinates*

OpenGL Camera

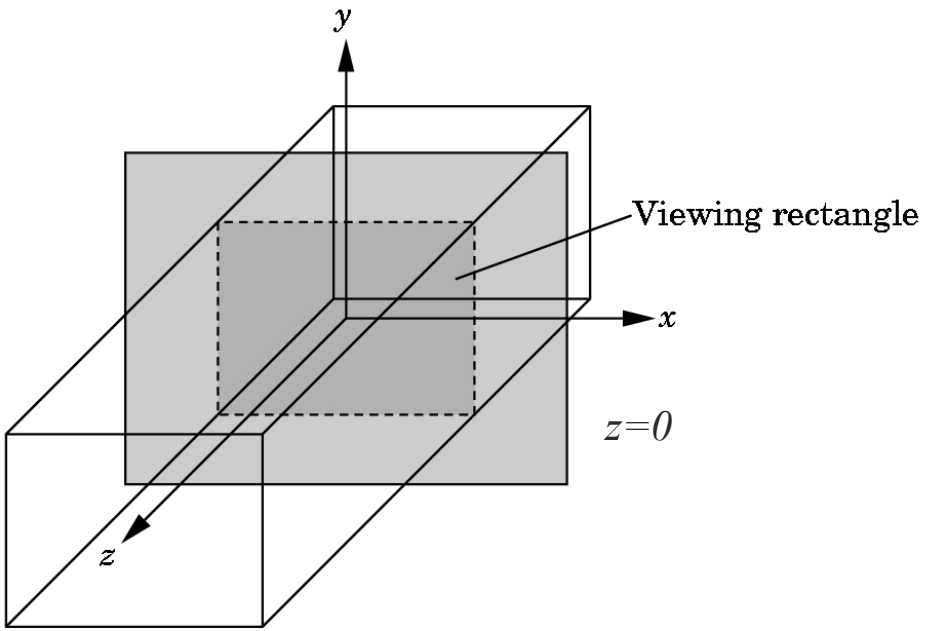
- OpenGL places a camera at the origin pointing in the negative z direction
- The default viewing volume

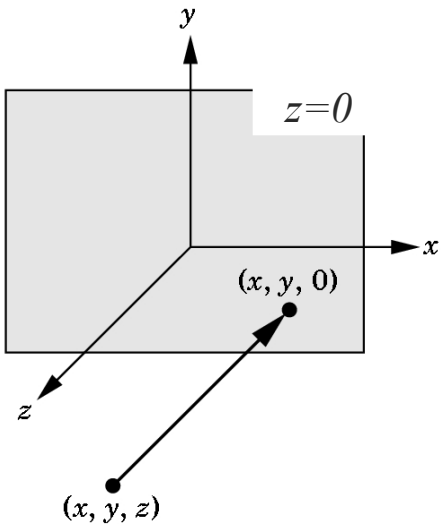
is a box centered at the origin with a side of length 2



Orthographic Viewing

In the default orthographic view, points are projected forward along the z axis onto the plane $z=0$





Projection Transformation

- Transformations are performed through multiplying a matrix onto the current matrix
  - `glMatrixMode(GL_PROJECTION);`
  - `glLoadIdentity();`
- Defines the view volume, i.e. what is visible, and what is to be clipped off.

Orthographical Projection

- Creates a rectangular viewing volume
- Distance from camera does not affect size
- Creates a matrix for projecting 2D coordinates onto the screen and multiply the current projection matrix by it

```
void gluOrtho2D(GLdouble left, GLdouble
right, GLdouble bottom, GLdouble top);
```

Two- and three-dimensional viewing

- In `glOrtho(left, right, bottom, top, near, far)` the near and far distances are measured from the camera
- Two-dimensional vertex commands place all vertices in the plane `z=0`
- If the application is in two dimensions, we can use the function

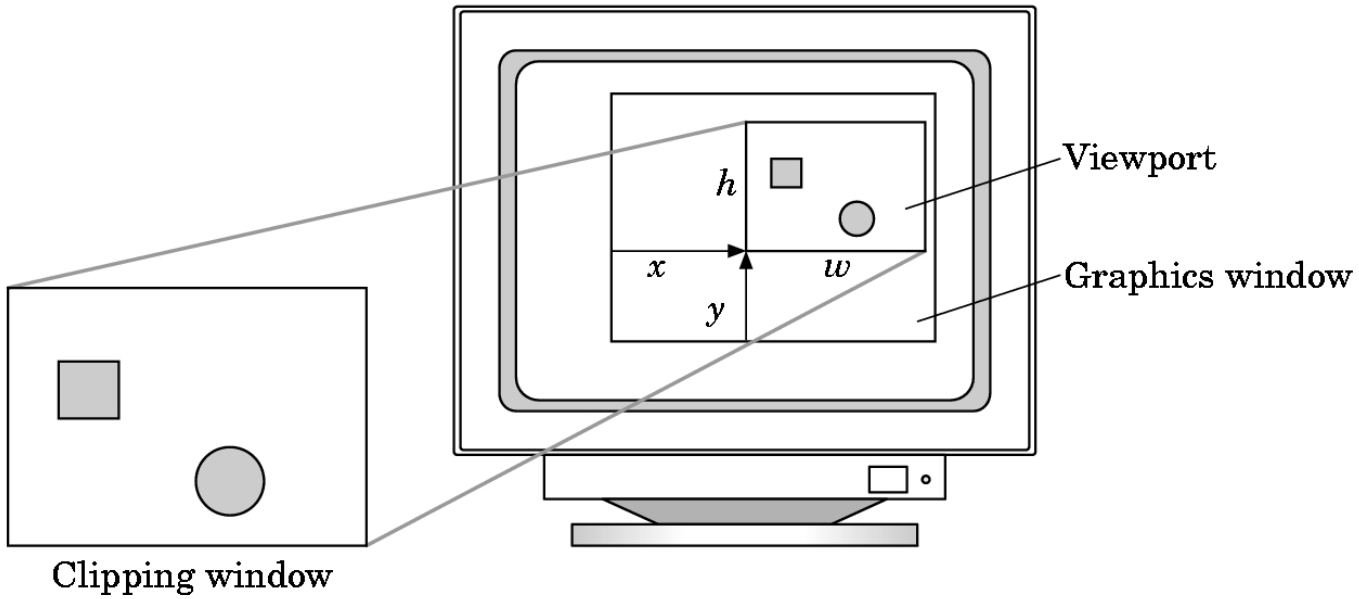
  `gluOrtho2D(left,right,bottom,top)`
- In two dimensions, the view or clipping volume becomes a *clipping window*

Set up viewing

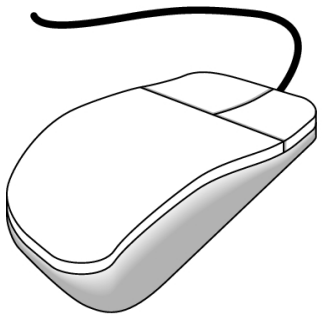
```
glMatrixMode(GL_PROJECTION);
glLoadIdentity ();
glOrtho(-1.0,1.0,-1.0,1.0,-1.0,1.0);
// or glOrtho2D(-1.0,1.0,-1.0,1.0);

glMatrixMode(GL_MODELVIEW);
```

Viewports

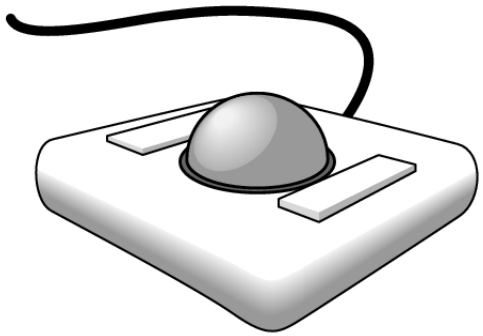
- Do not have use the entire window for the image: **`glViewport(x,y,w,h)`**
- Values in pixels (screen coordinates)



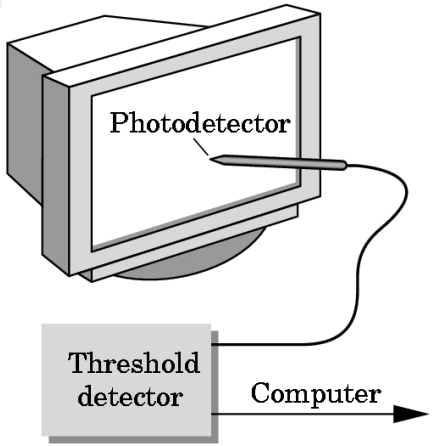
Physical Devices



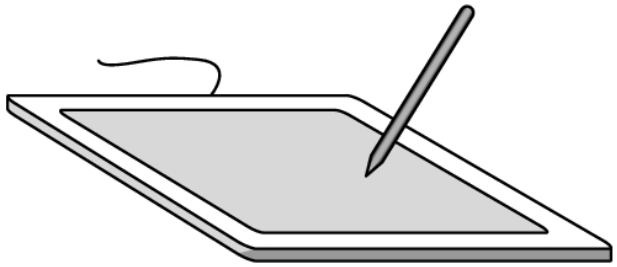
mouse



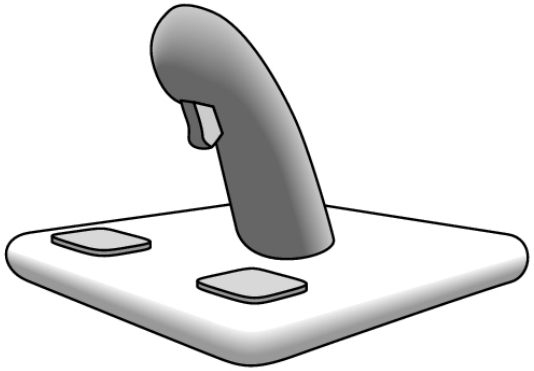
trackball



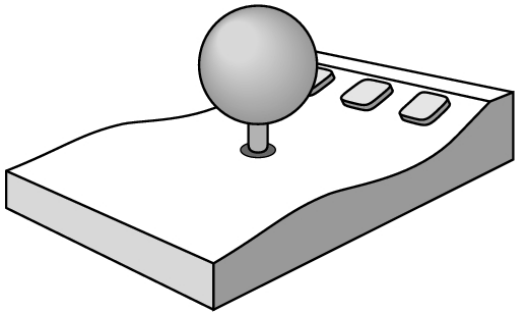
light pen



data tablet



joy stick



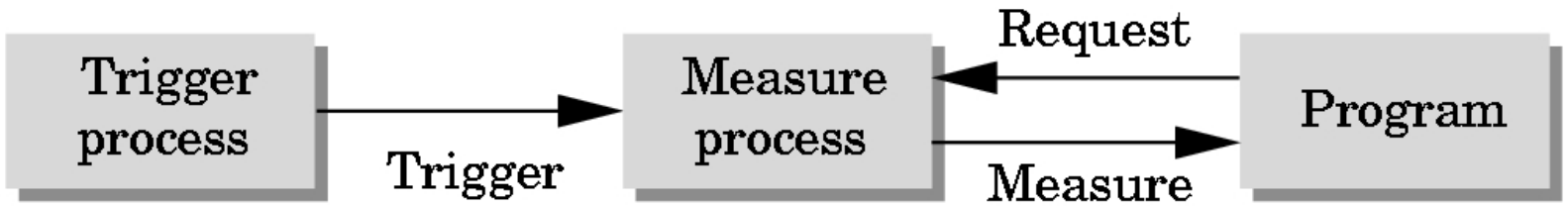
space ball

Input Modes

- Input devices contain a *trigger* which can be used to send a signal to the operating system
  - Button on mouse
  - Pressing or releasing a key

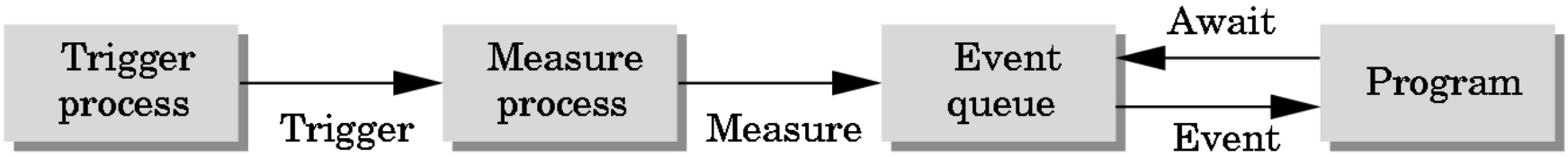
Request Mode

- Input provided to program only when user triggers the device
- Typical of keyboard input
  - Can erase (backspace), edit, correct until enter (return) key (the trigger) is depressed



Event Mode

- Most systems have more than one input device, each of which can be triggered at an arbitrary time by a user
- Each trigger generates an *event* whose measure is put in an *event queue* which can be examined by the user program

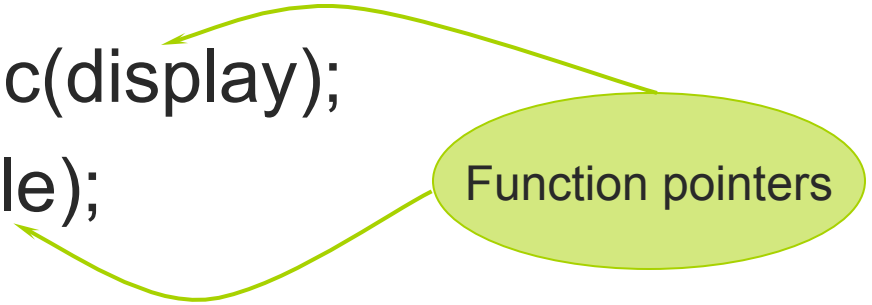


Event Types

- Window: resize, expose, iconify
- Mouse: click one or more buttons
- Motion: move mouse
- Keyboard: press or release a key
- Idle: nonevent
  - Define what should be done if no other event is in queue

Callback functions

- Called when something happens
  - Window resize or redraw
  - User input
  - Animation
- Register callbacks with GLUT
  - glutDisplayFunc(display);
  - glutIdleFunc(idle);



GLUT Event Callbacks

- Callback actions:

```
glutDisplayFunc();              // window redraw
glutKeyboardFunc();           // a key is struck
glutReshapeFunc();            // window reshapes
glutMouseFunc();          // mouse button press
glutMotionFunc();             // mouse moves and
                                  // button held
glutPassiveMotionFunc();      // mouse moves
glutIdleFunc();                             // on
   idle
```

Important callbacks

- Display
  - Called every time the main GL window is drawn/refreshed
  - This is where you do all of your rendering
- Idle
  - Use for animation and continuous update
  - Update some variables/data structures and call **`glutPostRedisplay()`**

GLUT Event Loop

- Remember that the last line in **`main.c`** for a program using GLUT must be

  `glutMainLoop();`

  which puts the program in an infinite event loop
- In each pass through the event loop, GLUT
  - looks at the events in the queue
  - for each event in the queue, GLUT executes the appropriate callback function if one is defined
  - if no callback is defined for the event, the event is ignored

Posting redisplays

- Many events may invoke the display callback function
  - Can lead to multiple executions of the display callback on a single pass through the event loop
- We can avoid this problem by instead using

```
glutPostRedisplay();
```

  which sets a flag.
- GLUT checks to see if the flag is set at the end of the event loop
- If set then the display callback function is executed

Using globals

- The form of all GLUT callbacks is fixed
  - `void display()`
  - `void mouse(GLint button, GLint state, GLint x, GLint y)`
- Must use globals to pass information to callbacks

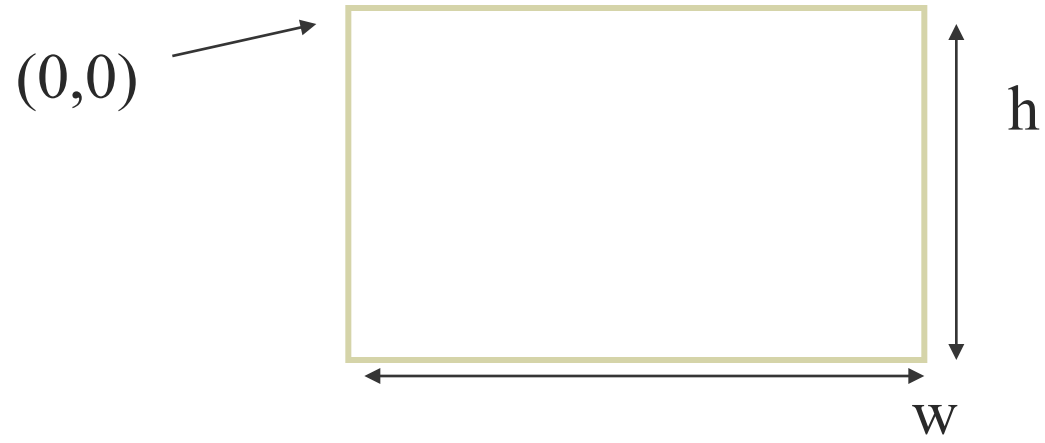
```
float t; /*global */

void display() {
/* draw something that depends on t
}
```

Mouse

- `void glutMouseFunc(void (*func)(int button, int state, int x, int y));`
  - `GLUT_LEFT_BUTTON`
  - `GLUT_RIGHT_BUTTON`
  - `GLUT_MIDDLE_BUTTON`
  - `GLUT_UP`
  - `GLUT_DOWN`
- `void glutMotionFunc(void (*func) (int x,int y));`
- `void glutPassiveMotionFunc(void (*func) (int x, int y));`

Positioning

- A window is measured in pixels with the origin at the top-left corner
  - Consequence of refresh done top to bottom
- OpenGL uses a world coordinate system with origin at the bottom left
  - Must invert y coordinate returned by callback by height of window
  - *y = h – y;*



Terminating a program

- In our original programs, there was no way to terminate them through OpenGL
- We can use the simple mouse callback

```
void mouse(int btn, int state, int x, int y){
   if(btn==GLUT_RIGHT_BUTTON && state==GLUT_DOWN)
      exit(0);
}
```

Using the keyboard

- `glutKeyboardFunc(keyboard)`
- `Void keyboard(unsigned char key,`
  `int x, int y)`
  - ASCII code of key depressed and mouse location
  - Note GLUT does not recognize key release as an event

Keyboard

```
void keyboard (unsigned char key, int x, int y){
      switch(key) {
      case 'q': case 'Q': case 27:
        exit (0);
        break;
      case 'p': case 'P':
        paused = 1;
        break;
      }
}
```

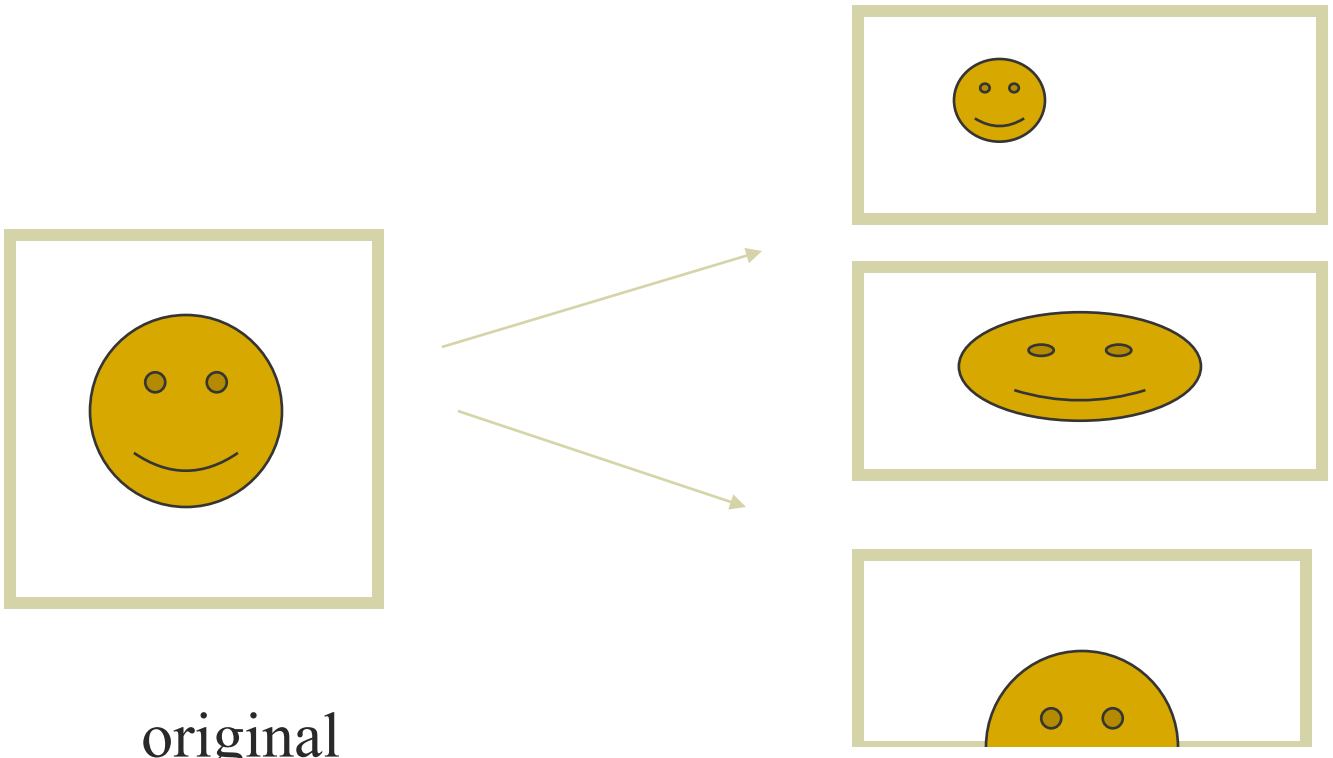
Key modifiers and special keys

- `int glutGetModifiers(void);`
  - `GLUT_ACTIVE_SHIFT`
  - `GLUT_ACTIVE_ALT`
  - `GLUT_ACTIVE_CTRL`
- `void glutSpecialFunc(void (*func) (int key, int x, int y));`
  - `GLUT_KEY_F1 (F2 … F12)`
  - `GLUT_KEY_UP (DOWN, LEFT, RIGHT)`
  - `GLUT_KEY_PAGEUP (PAGEDOWN, HOME, END, INSERT)`
  - passing in **`NULL`** will cause these keys to be ignored

Reshaping the window

- Resize the OpenGL display window by pulling the corner of the window
- What happens to the display?
  - Must redraw from application
  - Two possibilities
    - Display part of world
    - Display whole world but force to fit in new window
      - **Can alter aspect ratio**

Reshape possibilities



Window reshape

- Viewport transformation:
  - Maps image into window coordinates
  - Mostly called in the resize function
- **`void glutReshapeFunc(void (*func)(int width, int height));`**

```
void reshape(int w, int h) {
  // Set the viewport to be the entire window
  glViewport(0, 0, (GLint)w, (GLint)h);
}
```

The Reshape callback

- A redisplay is posted automatically at end of execution of the callback
- GLUT has a default reshape callback but you probably want to define your own

- The reshape callback is good place to put camera functions because it is invoked when the window is first opened and every time it is changed

Example Reshape

- Project the viewport to window coordinate system

```
void reshape(int w, int h) {
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION); /* switch matrix mode */
  glLoadIdentity();

  gluOrtho2D(0.0, w, 0.0, h);

  glMatrixMode(GL_MODELVIEW); /* return to modelview mode */
}
```