

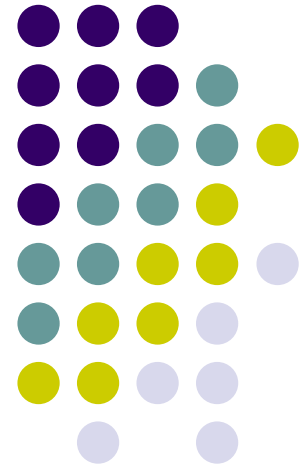
Computer Graphics (4731)

Lecture 4: 2D Graphics Systems

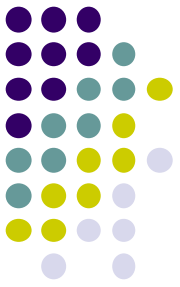
(Drawing Polylines, tiling, & Aspect Ratio)

Prof Emmanuel Agu

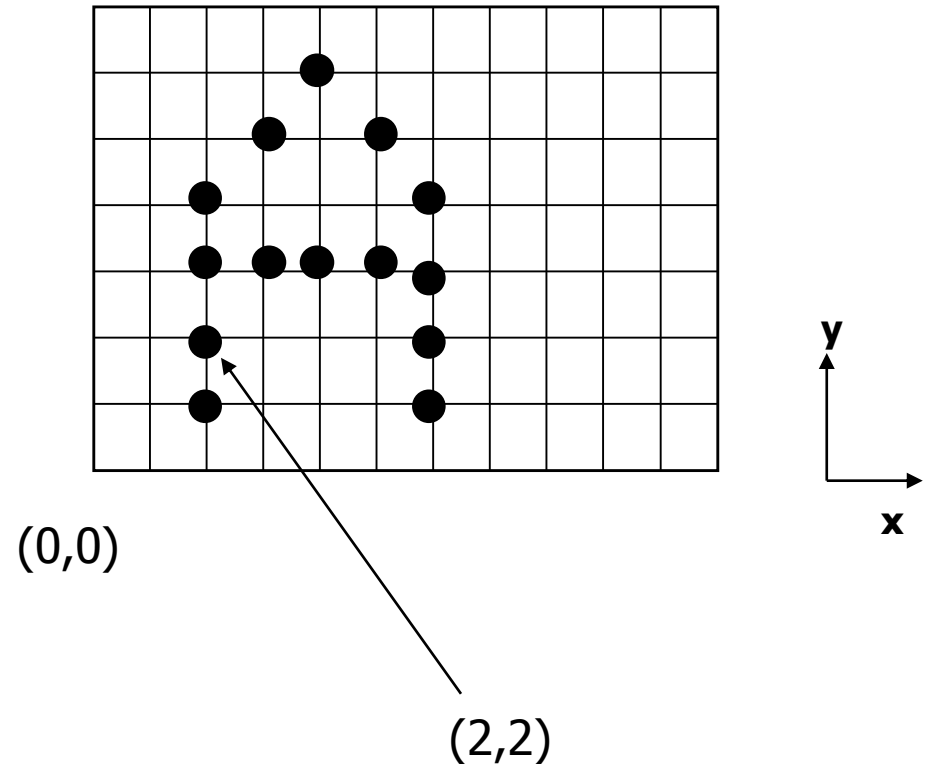
*Computer Science Dept.
Worcester Polytechnic Institute (WPI)*

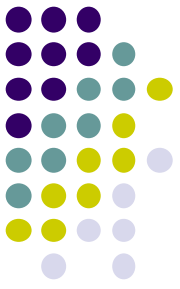


Screen Coordinate System



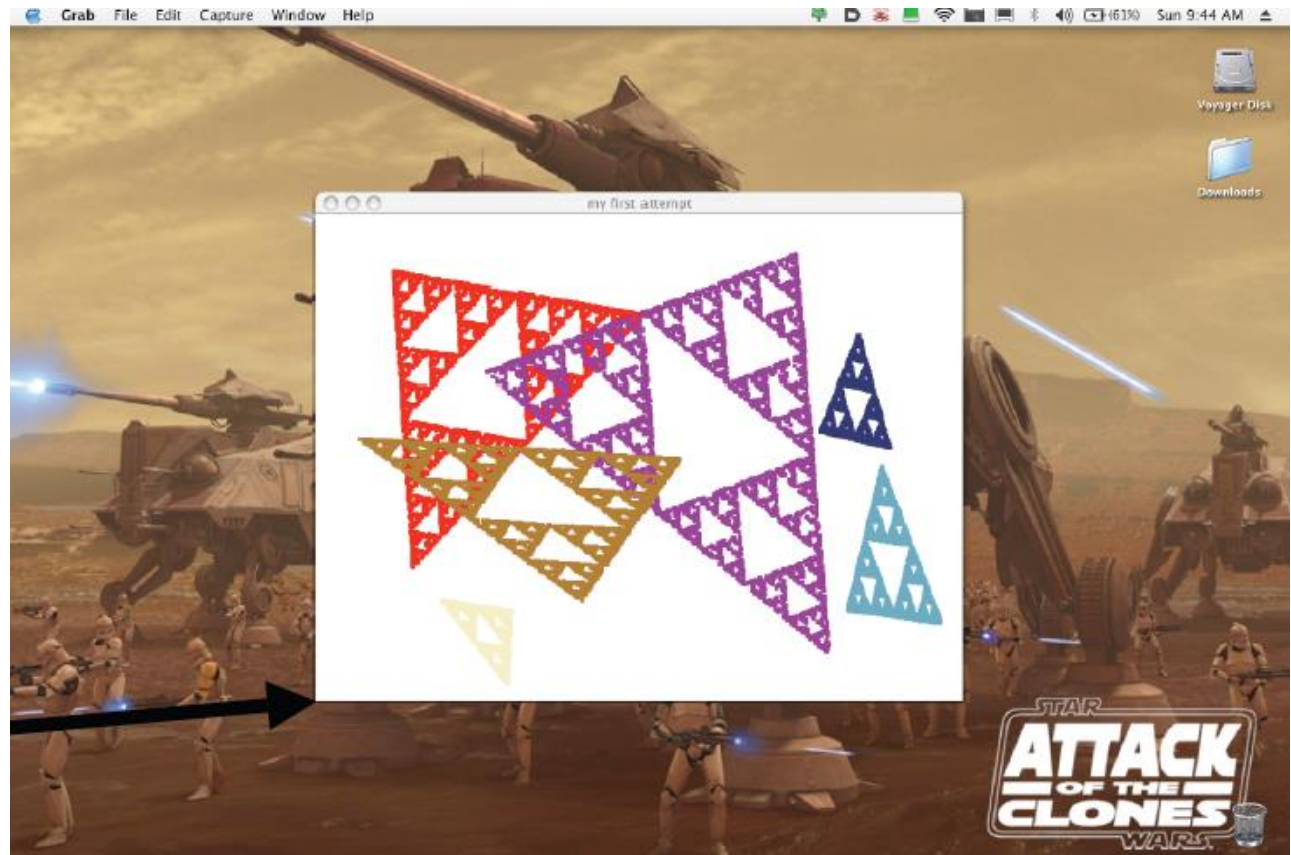
- Screen: 2D coordinate system (WxH)
- 2D Regular Cartesian Grid
- Origin (0,0): lower left corner (OpenGL convention)
- Horizontal axis – x
- Vertical axis – y
- Pixel positions: grid intersections





Screen Coordinate System

(0,0) is lower left corner of **OpenGL Window**.
NOT lower left corner of entire desktop

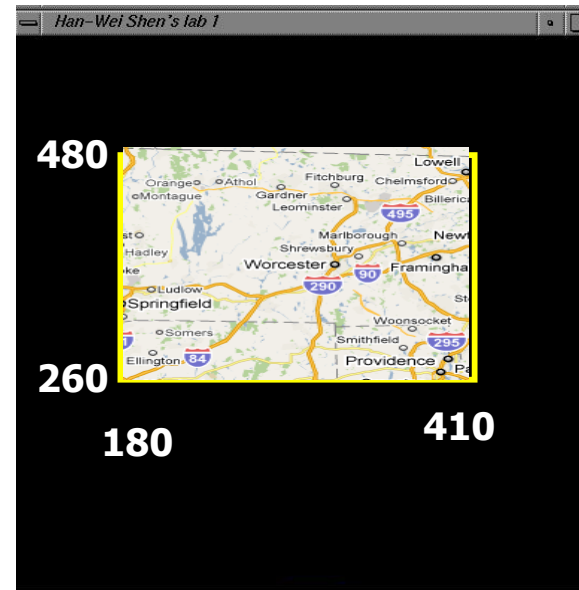
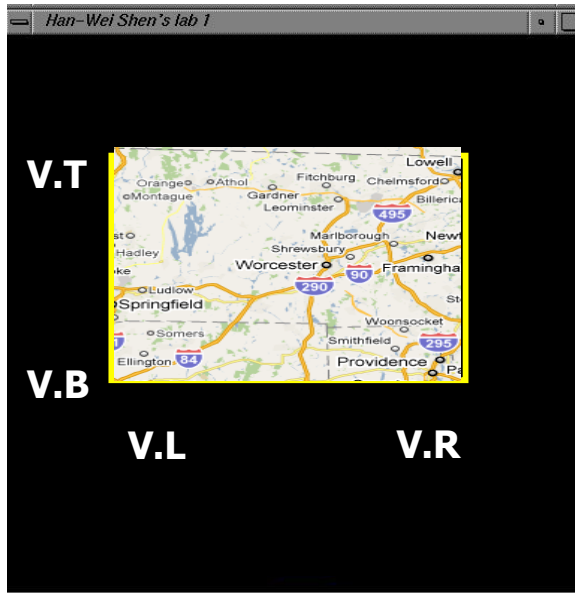


OpenGL's (0,0) →

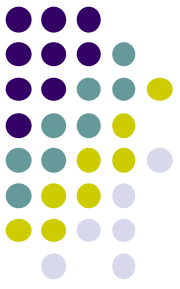


Defining a Viewport

- Can draw to any rectangle (sub-area of screen)
- **Viewport:** Area of screen we want to draw to
- To define viewport
`glViewport(left, bottom, width, height)`
or `glViewport(V.L, V.B, V.R - V.L, V.T - V.B)`
e.g. `glViewport(180, 260, (410 - 180), (480 - 260))`



Recall: OpenGL Skeleton



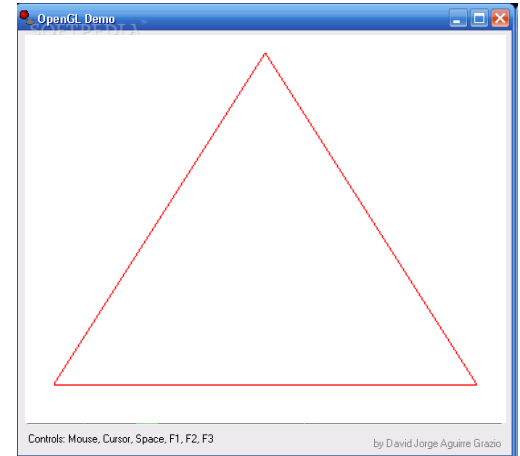
```
void main(int argc, char** argv){
    // First initialize toolkit, set display mode and create window
    glutInit(&argc, argv);    // initialize toolkit
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize(640, 480);
    glutInitWindowPosition(100, 150);
    glutCreateWindow("my first attempt");
    glewInit( );
```

```
// ... now register callback functions
```

```
glutDisplayFunc(myDisplay);
glutReshapeFunc(myReshape);
glutMouseFunc(myMouse);
glutKeyboardFunc(myKeyboard);
```

```
myInit( );
glutMainLoop( );
```

```
}
```



```
void mydisplay(void){
    glClear(GL_COLOR_BUFFER_BIT);
    glDrawArrays(GL_LINE_LOOP, 0, 3);
    glFlush( );
}
```

Note: default viewport is entire created window

Example: Changing Viewport

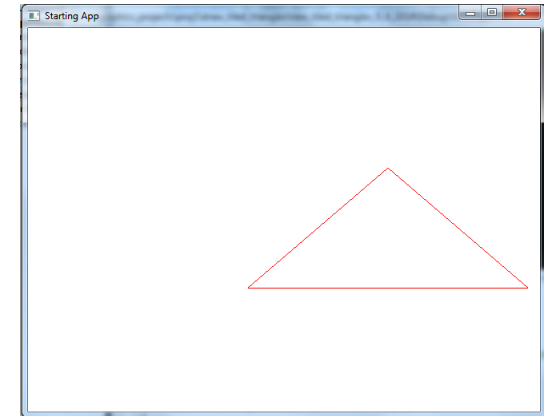


How to change viewport to:

Bottom left corner at (100,80)

Width changes to 700, height changes to 300??

```
void main(int argc, char** argv){
// First initialize toolkit, set display mode and create window
glutInit(&argc, argv); // initialize toolkit
glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
glutInitWindowSize(640, 480);
glutInitWindowPosition(100, 150);
glutCreateWindow("my first attempt");
glewInit( );
```



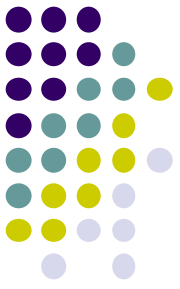
// ... now register callback functions

```
glutDisplayFunc(myDisplay);
glutReshapeFunc(myReshape);
glutMouseFunc(myMouse);
glutKeyboardFunc(myKeyboard);
```

```
myInit( );
glutMainLoop( );
```

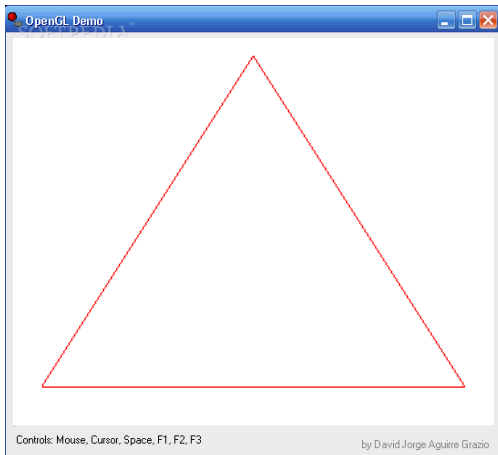
```
void mydisplay(void){
    glClear(GL_COLOR_BUFFER_BIT);
    glViewport(100,80,700,300);
    glDrawArrays(GL_LINE_LOOP, 0, 3);
    glFlush( );
}
```

Note: Set desired viewport, then draw

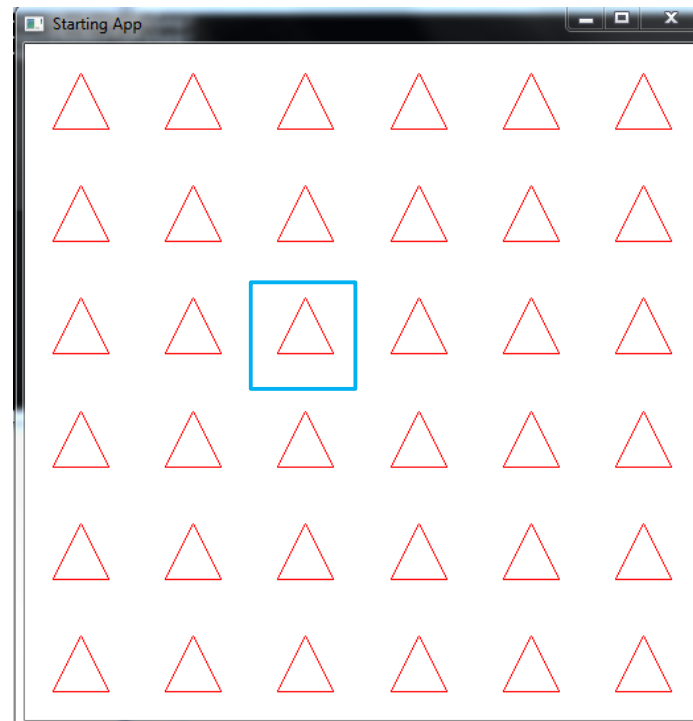


Tiling: Changing Viewport in a Loop

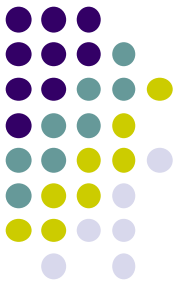
- **Problem:** Want to tile Triangle file on screen
- **Solution:** change viewport in loop, draw tiles



**One world
triangle**



Multiple tiled viewports



Tiling Triangle Code Snippet

- Set viewport, draw into tile in a loop
- Code snippet:

```
float w, h;
```

```
w = width / 6;
```

```
h = height / 6;
```

```
for (int k=0; k<6; k++) {
```

```
    for (int m=0; m<6; m++) {
```

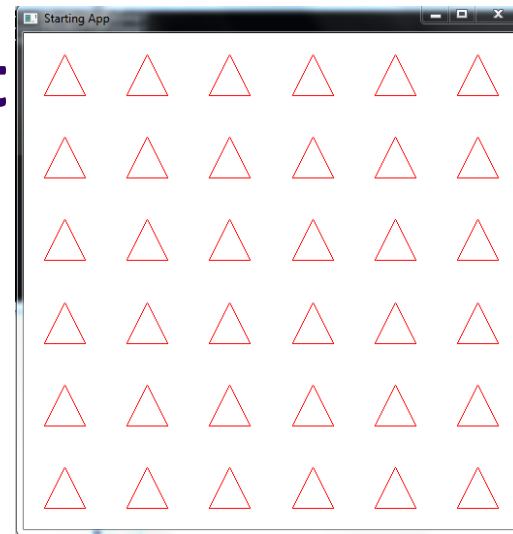
```
        glVertex(k * w, m * h, w, h);
```

```
        glDrawArrays(GL_LINE_LOOP, 0, NumPoints);
```

```
    }
```

```
}
```


Example: Tiling, Changing Viewport



```
void main(int argc, char** argv){
    // First initialize toolkit, set display mode and create window
    glutInit(&argc, argv);    // initialize toolkit
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize(640, 480);
    glutInitWindowPosition(100, 150);
    glutCreateWindow("my first attempt");
    glewInit( );
```

```
// ... now register callback functions
glutDisplayFunc(myDisplay);
glutReshapeFunc(myReshape);
glutMouseFunc(myMouse);
glutKeyboardFunc(myKeyboard);
```

```
myInit( );
glutMainLoop( );
```

```
void mydisplay(void){
    glClear(GL_COLOR_BUFFER_BIT);
    float w, h;

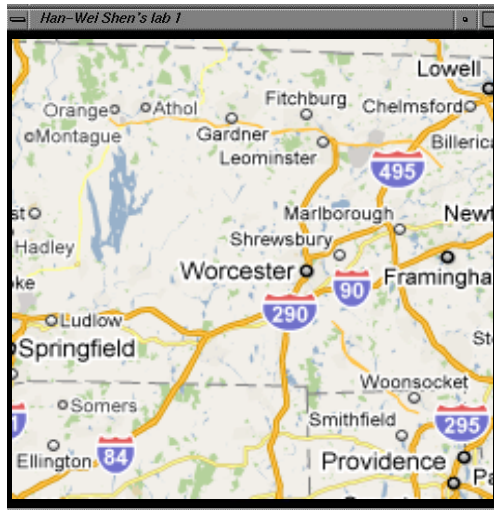
    w = width / 6; h = height / 6;

    for (int k=0; k<6; k++) {
        for (int m=0; m<6; m++) {
            glViewport(k * w, m * h, w, h);
            glDrawArrays(GL_LINE_LOOP, 0, NumPoints)
        }
    }
    glFlush( );
}
```



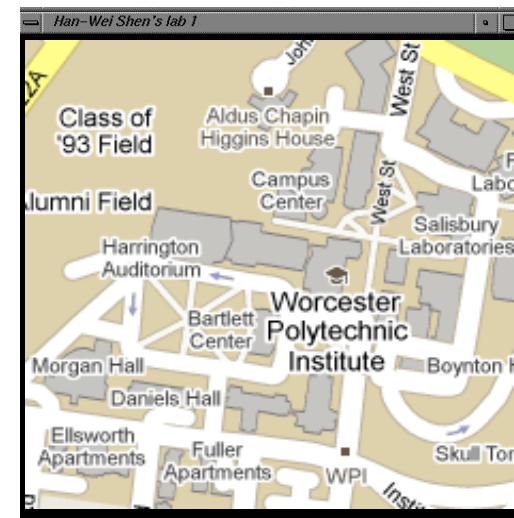
World Coordinate System

- Problems with drawing in screen coordinates:
 - **(x,y) dimensions in pixels:** one mapping, inflexible
 - Not application-specific, difficult to use
- **World coordinate:** application-specific
- E.g: Same screen area. Change input drawing (x,y) range

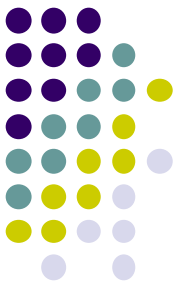


100 pixels = 30 miles

Change
World window
(mapping)



100 pixels = 0.25 miles



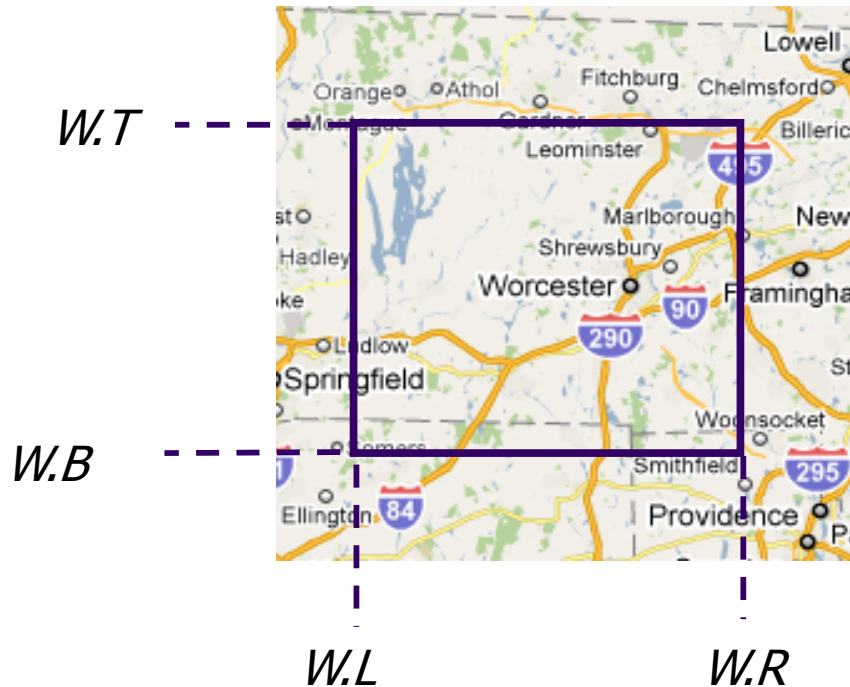
Using Window Coordinates

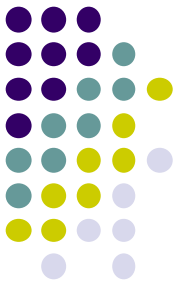
- Would like to:
 - Specify set **source** boundaries (extents) of original drawing in world coordinates (miles, meters, etc)
 - Display **target region** in screen coordinates (pixels)
- Programming steps:
 1. Define world window (original drawing extents)
 2. Define viewport (drawing extents on screen)
 3. Map drawings within window to viewport
- Mapping called ***Window-to-viewport mapping!***



World Coordinate System

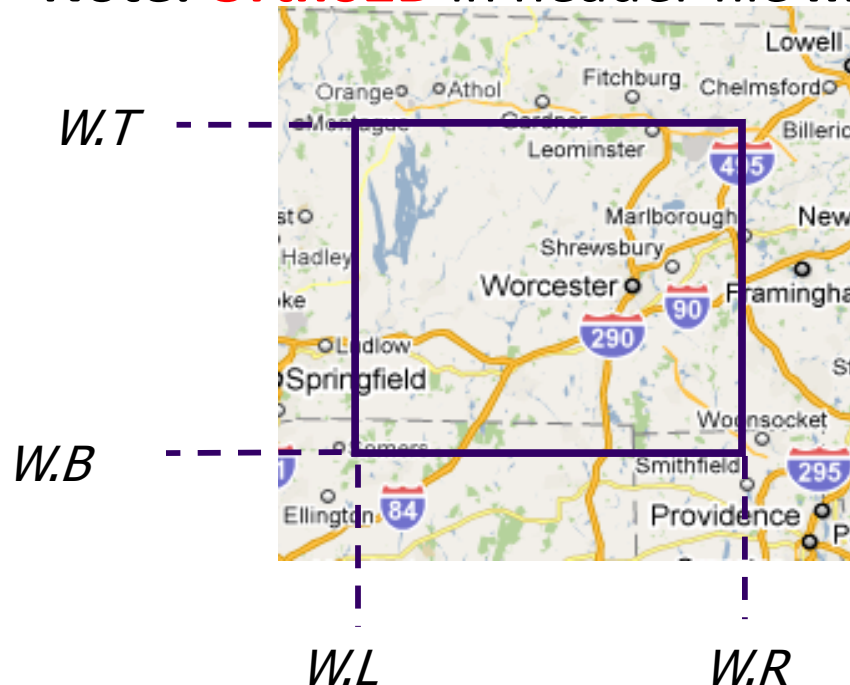
- **World Window:** region of **source** drawing to be rendered
- Rectangle specified by world window is drawn to screen
- Defined by (left, right, bottom, top) or (*W.L*, *W.R*, *W.B*, *W.T*)





Defining World Window

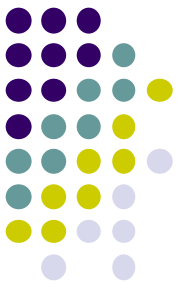
- `mat4 ortho = Ortho2D(left, right, bottom, top)`
Or `mat4 ortho = Ortho2D(W.L, W.R, W.B, W.T)`
- **Ortho2D** generates 4x4 matrix that scales input drawing
- **Note: Ortho2D** in header file **mat.h**





Drawing

- After setting world window (using `ortho2D`) and viewport (using `glviewport`),
 - Draw as usual with **`glDrawArrays`**



Apply ortho() matrix in Vertex Shader

- **One more detail:** Need to pass ortho matrix to shader
- Multiply each vertex by ortho matrix to scale input drawing
- Need to connect **ortho** matrix to **proj** variable in shader

```
mat4 ortho = Ortho2D( W.L, W.R, W.B, W.T );
```

Call Ortho2D in Main .cpp file

```
uniform mat4 Proj;  
in vec4 vPosition;  
  
void main( ){  
    gl_Position = Proj * vPosition;  
}
```

In vertex shader, multiply each vertex with **proj** matrix



Apply ortho() matrix in Vertex Shader

1. Include mat.h from book website (ortho2D declared in mat.h)

```
#include "mat.h"
```

2. Connect **ortho** matrix to **proj** variable in shader

```
mat4 ortho = Ortho2D( W.L, W.R, W.B, W.T );
```

```
ProjLoc = glGetUniformLocation( program, "Proj" );  
glUniformMatrix4fv( ProjLoc, 1, GL_TRUE, ortho );
```

Call Ortho2D in
Main .cpp file

```
uniform mat4 Proj;  
in vec4 vPosition;
```

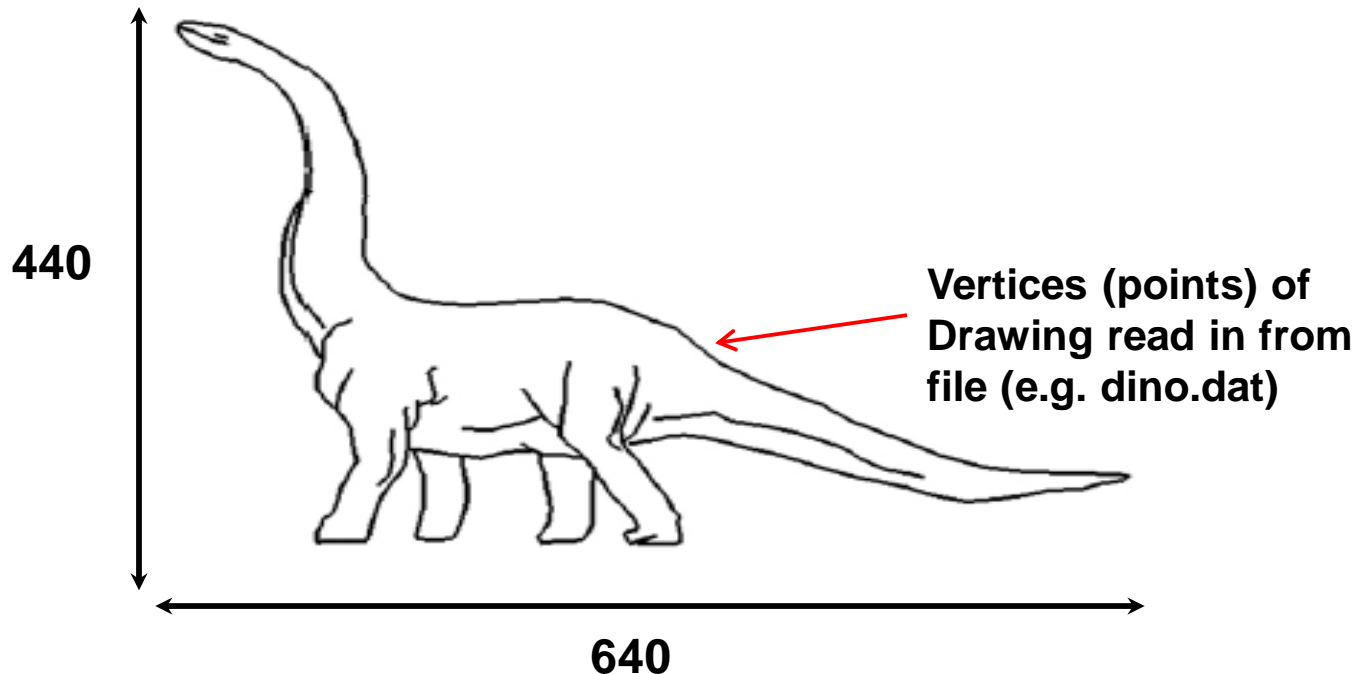
```
void main( ){  
    gl_Position = Proj * vPosition;  
}
```

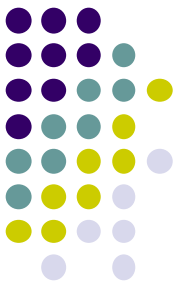
In shader, multiply each
vertex with **proj** matrix



Drawing Polyline Files

- May read in list of vertices defining a drawing
- **Problem:** want to draw single dino.dat on screen
- **Note:** size of input drawing may vary





Drawing Polyline Files

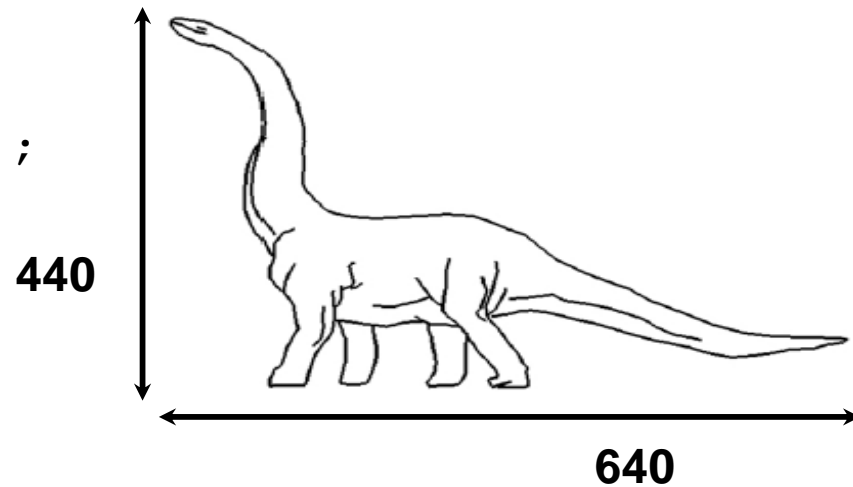
- **Problem:** want to draw single dino.dat on screen
- Code snippet:

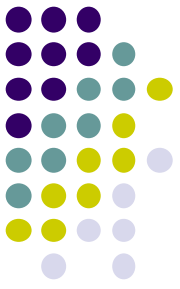
```
// set world window (left, right, bottom, top)
ortho = Ortho2D(0, 640.0, 0, 440.0);

// now set viewport (left, bottom, width, height)
glViewport(0, 0, 64, 44);

// Draw polyline file
drawPolylineFile(dino.dat);
```

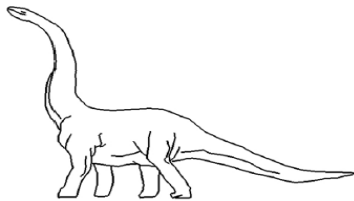
Question: What if I wanted to draw the bottom quadrant of polyline?





Tiling using W-to-V Mapping

- **Problem:** Want to tile polyline file on screen
- **Solution:** W-to-V in loop, adjacent tiled viewports



**One world
Window**

a)



Multiple tiled viewports

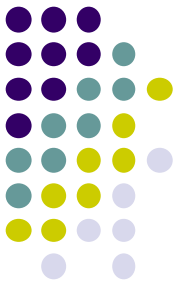


Tiling Polyline Files

- Problem: want to tile dino.dat in 5x5 across screen
- Code snippet:

```
// set world window
ortho = Ortho2D(0, 640.0, 0, 440.0);

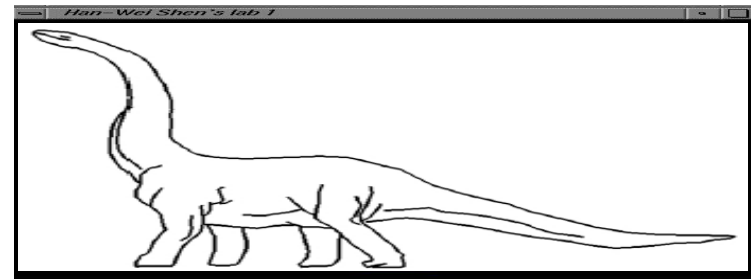
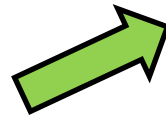
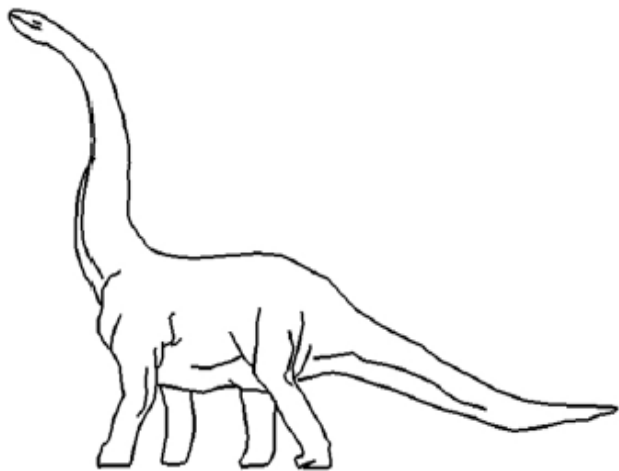
for(int i=0;i < 5;i++)
{
    for(int j = 0;j < 5; j++)
    { // .. now set viewport in a loop
        glViewport(i * 64, j * 44; 64, 44);
        drawPolylineFile(dino.dat);
    }
}
```



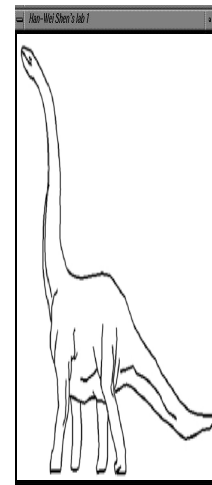
Maintaining Aspect Ratios

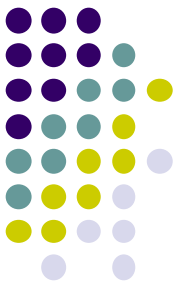
- Aspect ratio $R = \text{Width}/\text{Height}$
- What if window and viewport have different aspect ratios?
- Two possible cases:

Case a: viewport too wide



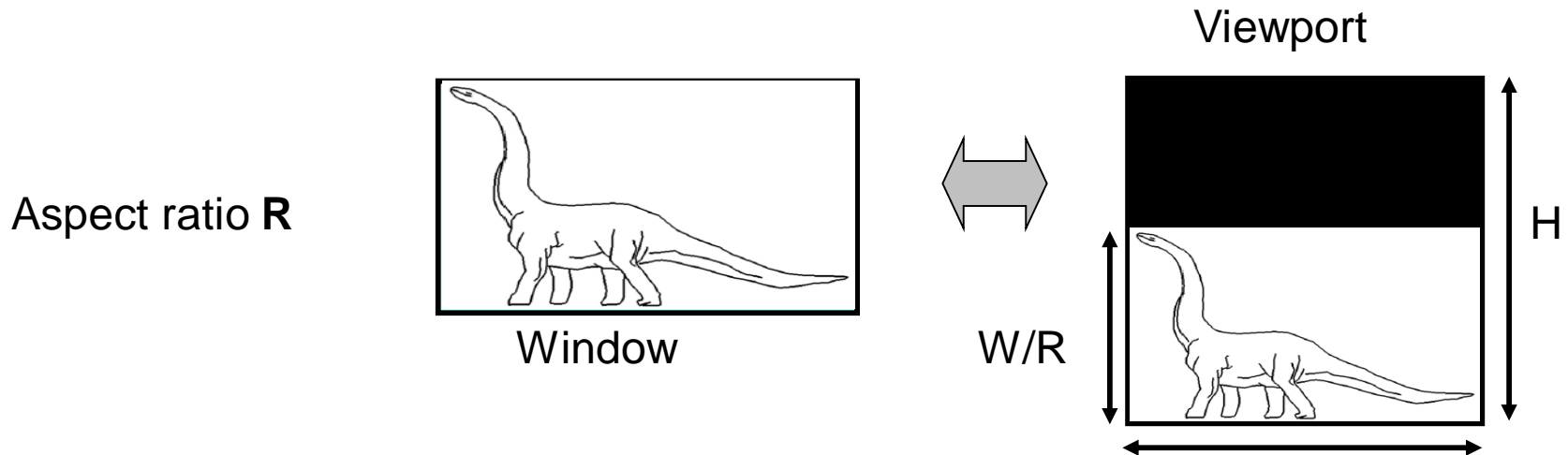
Case b: viewport too tall



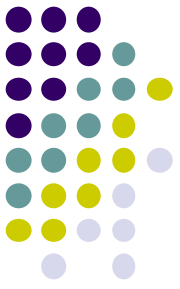


What if Window and Viewport have different Aspect Ratios?

- R = window aspect ratio, $W \times H$ = viewport dimensions
- Two possible cases:
 - **Case A ($R > W/H$):** map window to tall viewport?

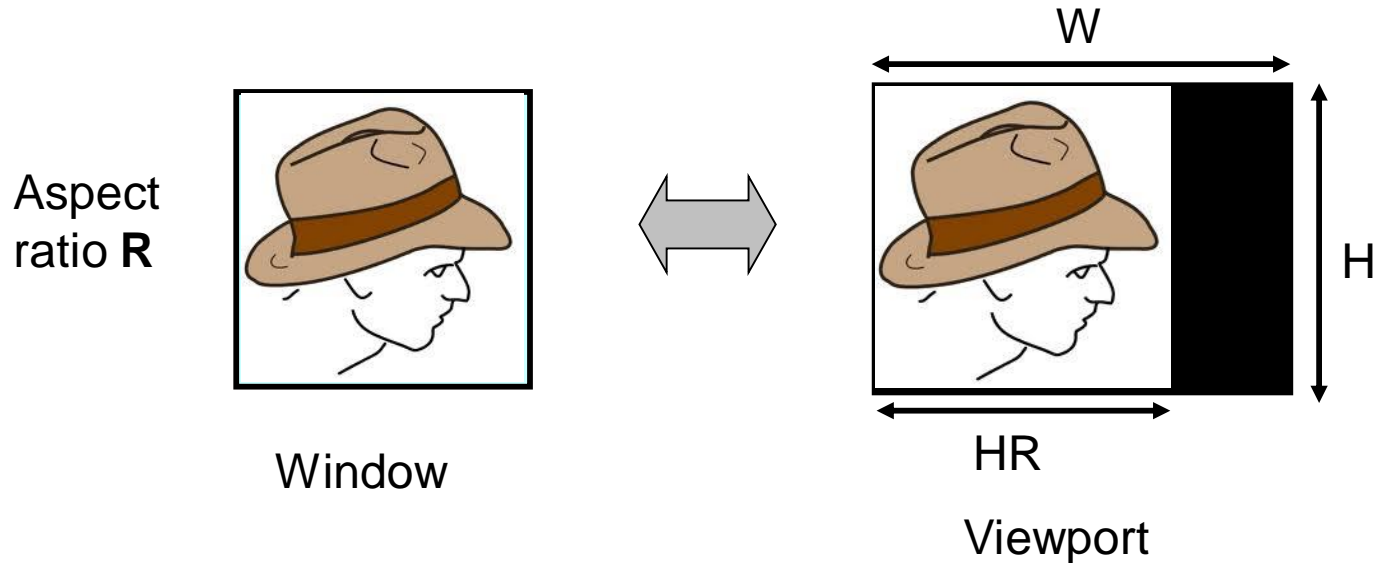


```
ortho = Ortho2D(left, right, bottom, top );  
R = (right - left) / (top - bottom);  
If ( $R > W/H$ )  
    glViewport(0, 0, W, W/R);
```

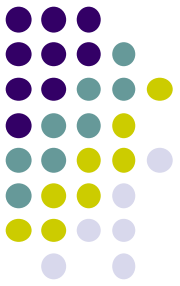


What if Window and Viewport have different Aspect Ratios?

- **Case B ($R < W/H$):** map window to wide viewport?



```
ortho = Ortho2D(left, right, bottom, top );  
R = (right - left)/(top - bottom);  
If( $R < W/H$ )  
    glViewport(0, 0,  $H*R$ , H);
```



reshape() function that maintains aspect ratio

```
// Ortho2D(left, right, bottom, top )is done previously,  
// probably in your draw function  
// function assumes variables left, right, top and bottom  
// are declared and updated globally
```

```
void myReshape(double W, double H ){  
    R = (right - left)/(top - bottom);  
  
    if(R > W/H)          // tall viewport  
        glViewport(0, 0, W, W/R);  
    else if(R < W/H)    // wide viewport  
        glViewport(0, 0, H*R, H);  
    else  
        glViewport(0, 0, W, H); // equal aspect ratios  
}
```




References

- Angel and Shreiner, Interactive Computer Graphics, 6th edition, Chapter 2
- Hill and Kelley, Computer Graphics using OpenGL, 3rd edition, Chapter 3