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

(0,0)

(2,2)
Screen Coordinate System

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

- Can draw to any rectangle (sub-area of screen)
- **Viewport**: Area of screen we want to draw to
- To define viewport

```cpp
glViewport(left, bottom, width, height)
```

or

```cpp
glViewport(V.L, V.B, V.R - V.L, V.T - V.B)
```

or

```cpp
glViewport(180, 260, (410 - 180), (480 - 260) )
```
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

100 pixels = 0.25 miles
Using Window Coordinates

- Would like to:
  - Specify set boundaries (extents) of original drawing in world coordinates (miles, meters, etc)
  - Display 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

- \texttt{mat4 ortho = Ortho2D(left, right, bottom, top)}
  
  Or \texttt{mat4 ortho = Ortho2D(W.L, W.R, W.B, W.T)}

- **Ortho2D** generates 4x4 matrix that scales input drawing

- **Note:** Ortho2D in header file \texttt{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

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

uniform mat4 Proj;
in vec4 vPosition;

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

In vertex shader, multiply each vertex with proj matrix

Call Ortho2D in Main .cpp file
Apply ortho( ) matrix in Vertex Shader

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

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

2. Connect ortho matrix to proj variable in shader

```cpp
mat4 ortho = Ortho2D( W.L, W.R, W.B, W.T );
ProjLoc = glGetUniformLocation( program, "Proj" );
glUniformMatrix4fv( ProjLoc, 1, GL_FALSE, ortho );
```

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

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

In shader, multiply each vertex with proj matrix

Call Ortho2D in Main .cpp file
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:**

```c
// 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 fine
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
Tiling Polyline Files

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

```cpp
// 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
  {
    // .. now set viewport in a loop
    glViewport(i * 64, j * 44; 64, 44);
    drawPolylineFile(dino.dat);
  }
}
```
Maintaining Aspect Ratios

- Aspect ratio $R = \frac{\text{Width}}{\text{Height}}$
- 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 x H** = viewport dimensions
- Two possible cases:
  - **Case A (R > W/H)**: map window to tall viewport?

```cpp
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?

```c
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)
        glViewport(0, 0, W, W/R);
    else if(R < W/H)
        glViewport(0, 0, H*R, H);
    else
        glViewport(0, 0, W, H);  // equal aspect ratios
}
References