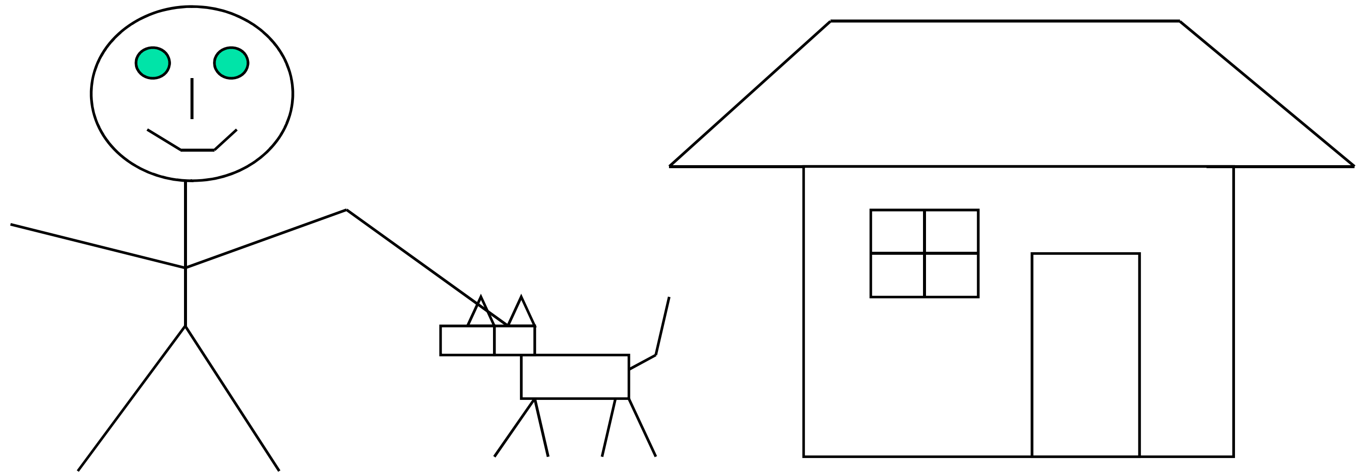
Drawing and Coordinate Systems



Coordinate Systems

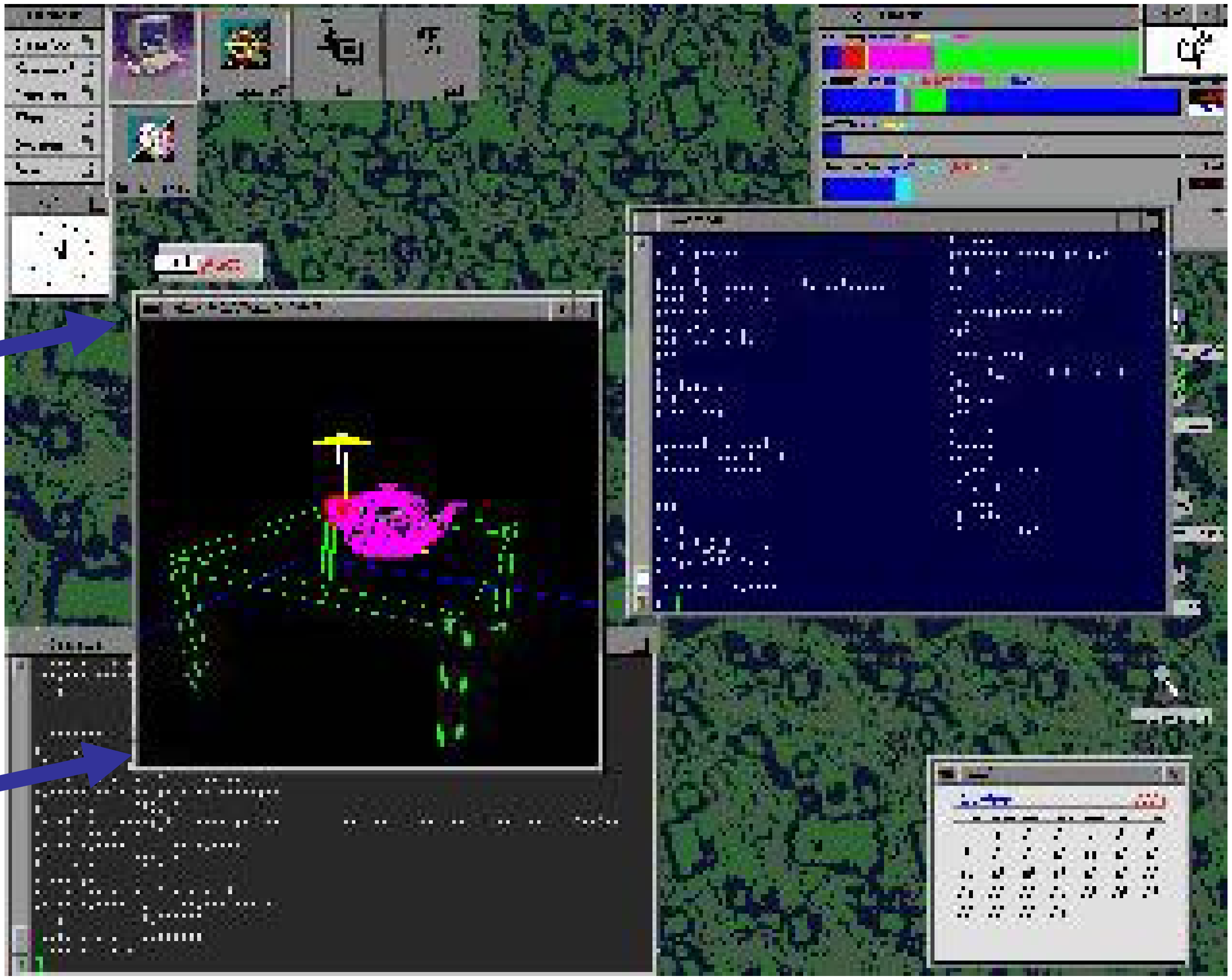
- World Coordinate system
- World window
- Screen Coordinate system
- Viewport
- Window to viewport mapping

Screen Coordinate System

Glut

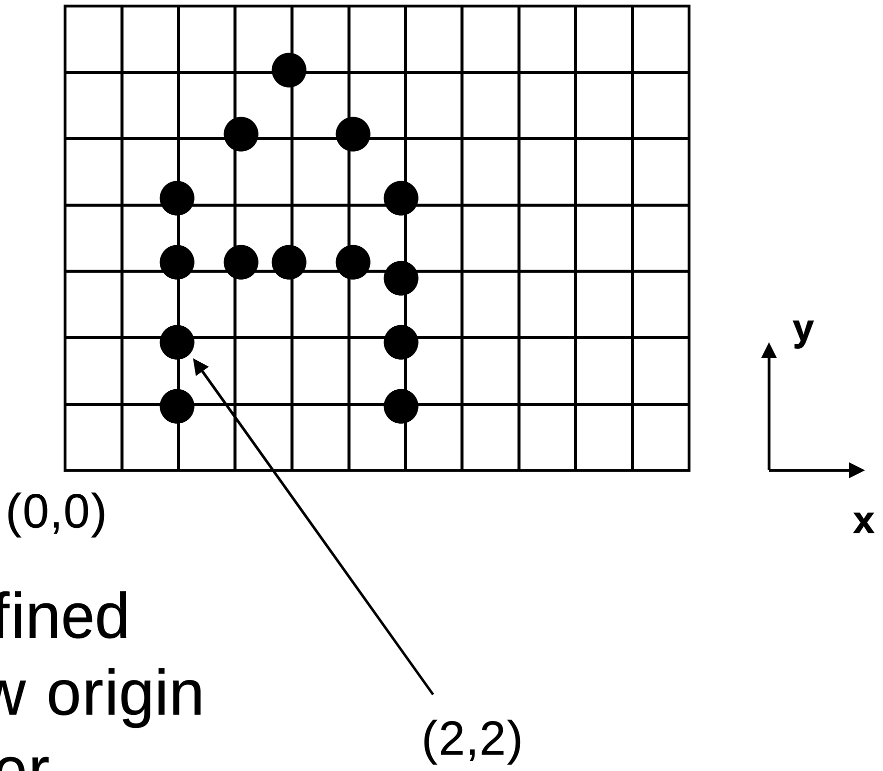
OpenGL

(0,0)



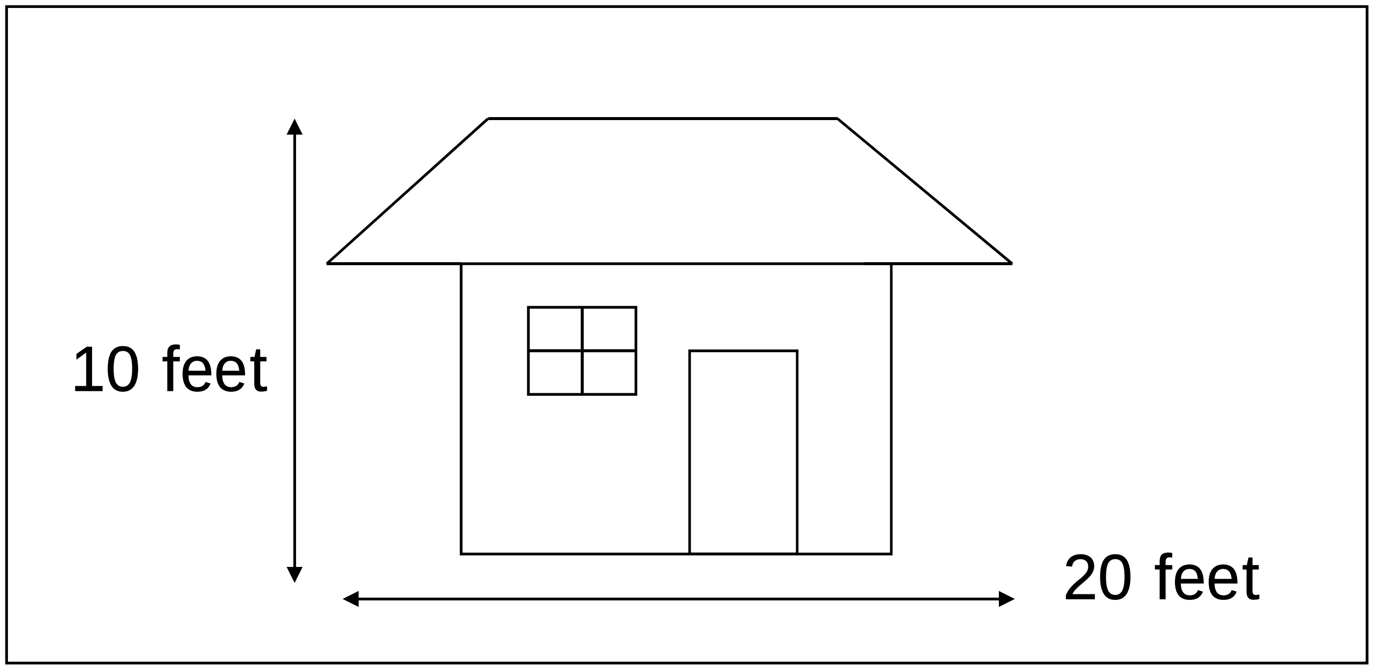
Screen Coordinate System

- 2D Regular Cartesian Grid
- Origin (0,0) at lower left corner (OpenGL convention)
- Horizontal axis – x
  Vertical axis – y
- Pixels are defined at the grid intersections
- This coordinate system is defined relative to the display window origin (OpenGL: the lower left corner of the window)



World Coordinate System

- Application specific – difficult to work directly in screen coordinates



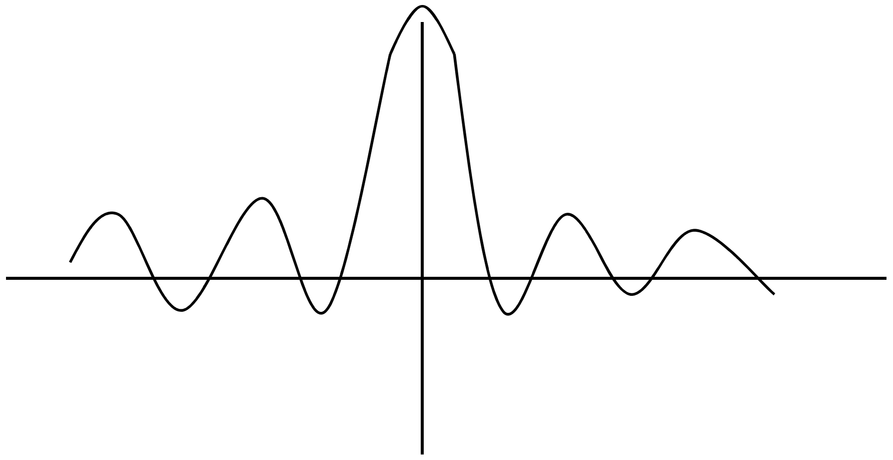
World Coordinate System

- Another example:

  plot a sinc function:

  sinc(x) = sin(PI*x)/PI*x

  x = -4 .. +4

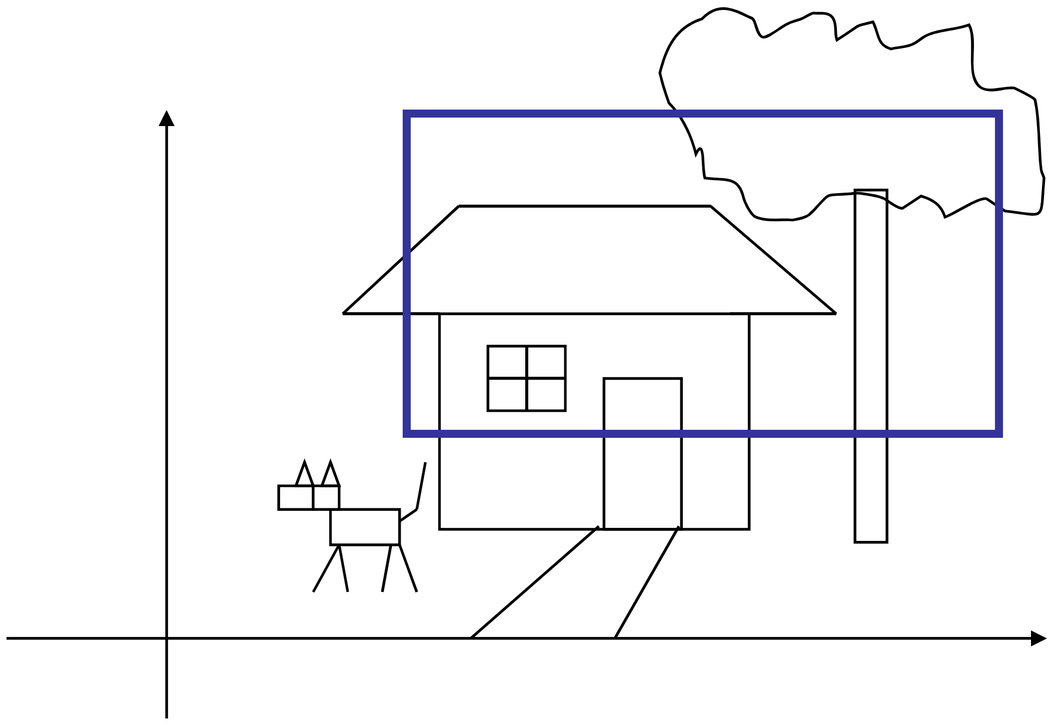


World Coordinate System

- It would be nice if we can use application specific coordinates – world coordinate system

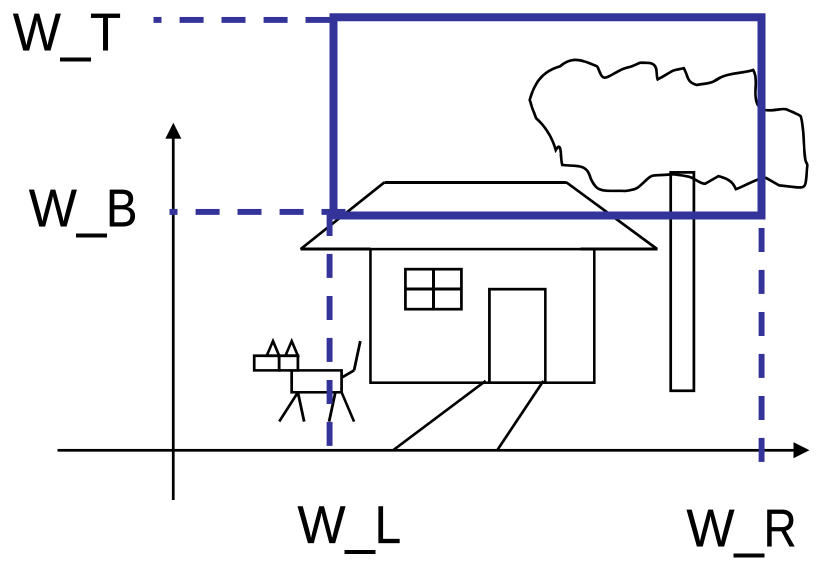
```
glBegin(GL_LINE_STRIP);
  for (x = -4.0; x <4.0; x+=0.1){
    GLfloat y = sin(3.14 * x) / (3.14 * x);
    glVertex2f (x,y);
  }

glEnd();
```

Define a world window



World Window

- World window – a rectangular region in the world that is to be displayed



$\longrightarrow$ Define by

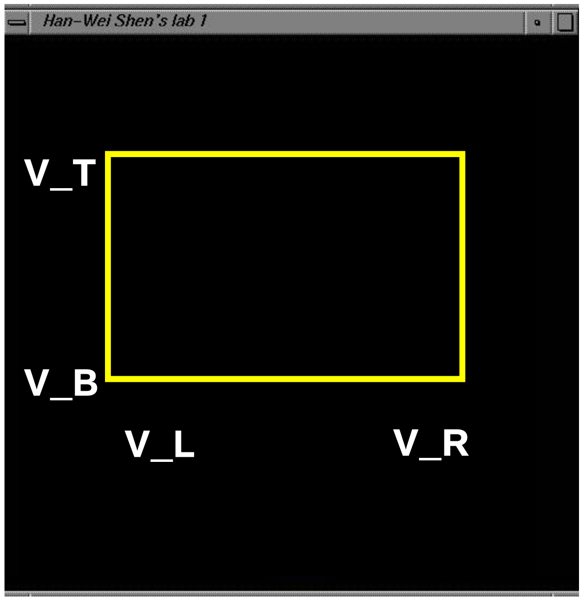
W_L, W_R, W_B, W_T

Use OpenGL command:

gluOrtho2D(left,right,bottom, top)

Viewport

- The rectangular region in the screen for displaying the graphical objects defined in the world window
- Defined in the screen coordinate system



```
glViewport(int  left, int  bottom,
                int  (right-left),
                int (top-bottom));
```

call this function before drawing (calling glBegin() and glEnd())

To draw in world coordinate system

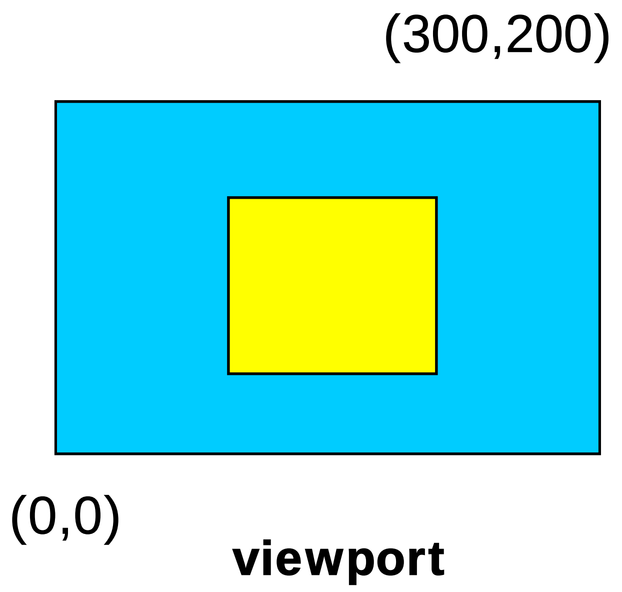
- Two tasks need to be done
  - Define a rectangular world window

    (call an OpenGL function)
  - Define a viewport (call an OpenGL function)
  - Perform window to viewport mapping

    (OpenGL internals will do this for you)

A simple example

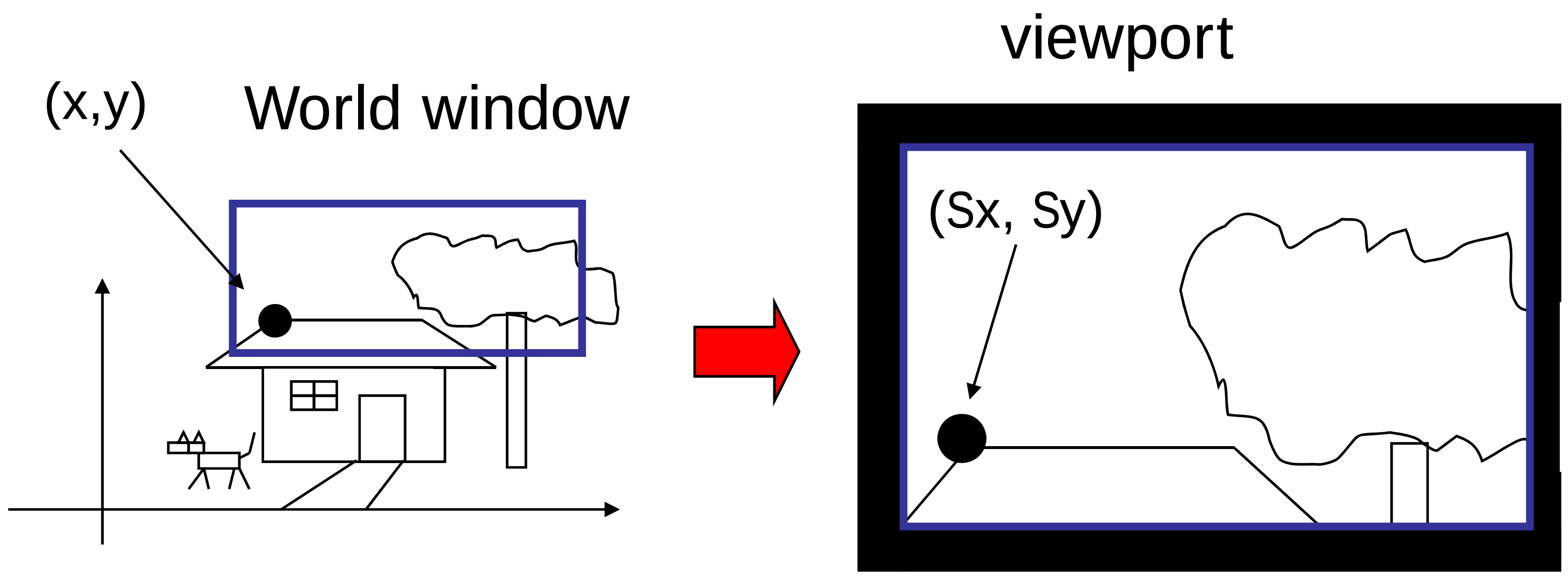
```
DrawQuad()
{
   glViewport(0,0,300,200);
   glMatrixMode(GL_PROJECTION);
   glLoadIdentity();
   gluOrtho2D(-1,1,-1,1);
   glBegin(GL_QUADS);
   glColor3f(1,1,0);
   glVertex2f(-0.5,-0.5);
   glVertex2f(+0.5,-0.5);
   glVertex2f(+0.5,+0.5);
   glVertex2f(-0.5,+0.5);
   glEnd();
}
```



How big is the quad?

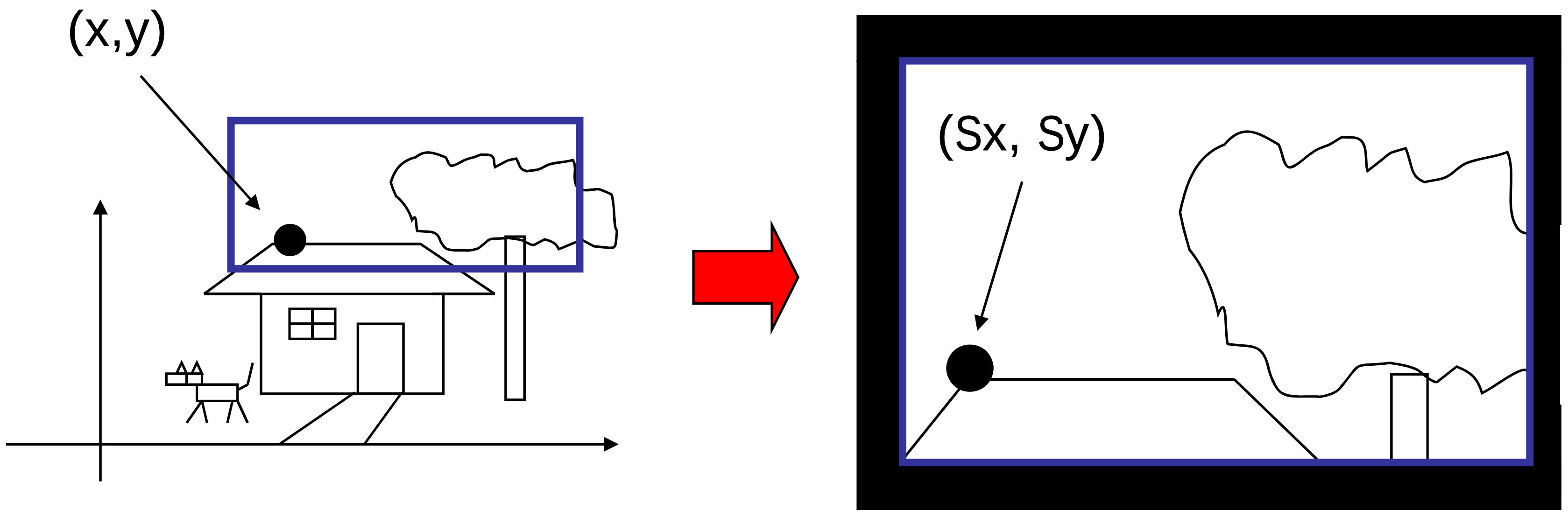
Window to viewport mapping

- The objects in the world window will then be drawn onto the viewport



Window to viewport mapping

- How to calculate (sx, sy) from (x,y)?



Window to viewport mapping

- First thing to remember – you don’t need to do it by yourself. OpenGL will do it for you
  - You just need to define the viewport (with glViewport()), and the world window (with gluOrtho2D())
- But we will look ‘under the hood’

Also, one thing to remember …

- A practical OpenGL issue
  - Before calling gluOrtho2D(), you need to have the following two lines of code –

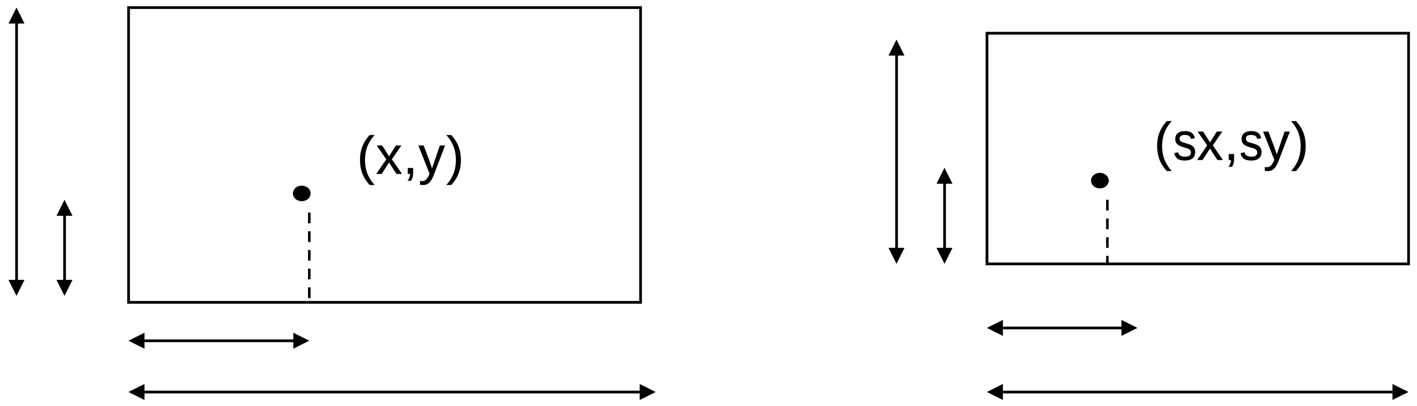
```
glMatrixMode(GL_PROJECTION);
glLoadIdentity();

gluOrtho2D(Left, Right, Bottom, Top);
```

Window to viewport mapping

- Things that are given:
  - The world window (W_L, W_R, W_B, W_T)
  - The viewport (V_L, V_R, V_B, V_T)
  - A point (x,y) in the world coordinate system
- Calculate the corresponding point (sx, sy) in the screen coordinate system

Window to viewport mapping

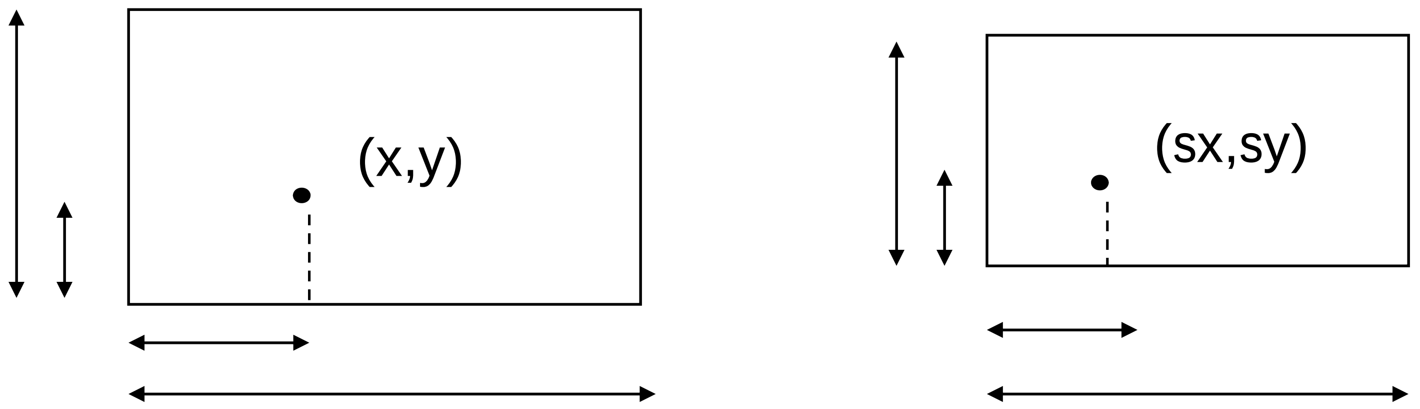
- Basic principle: the mapping should be proportional



(x – W_L) / (W_R – W_L) = (sx – V_L) / (V_R – V_L)

(y - W_B) / (W_T – W_B) = (sy – V_B) / (V_T – V_B)

Window to viewport mapping



(x – W_L) / (W_R – W_L) = (sx – V_L) / (V_R – V_L)

(y - W_B) / (W_T – W_B) = (sy – V_B) / (V_T – V_B)

sx = x * (V_R-V_L)/(W_R-W_L) - W_L * (V_R – V_L)/(W_R-W_L) + V_L

sy = y * (V_T-V_B)/(W_T-W_B) – W_B * (V_T-V_B)/(W_T-W_B) + V_B

Some practical issues

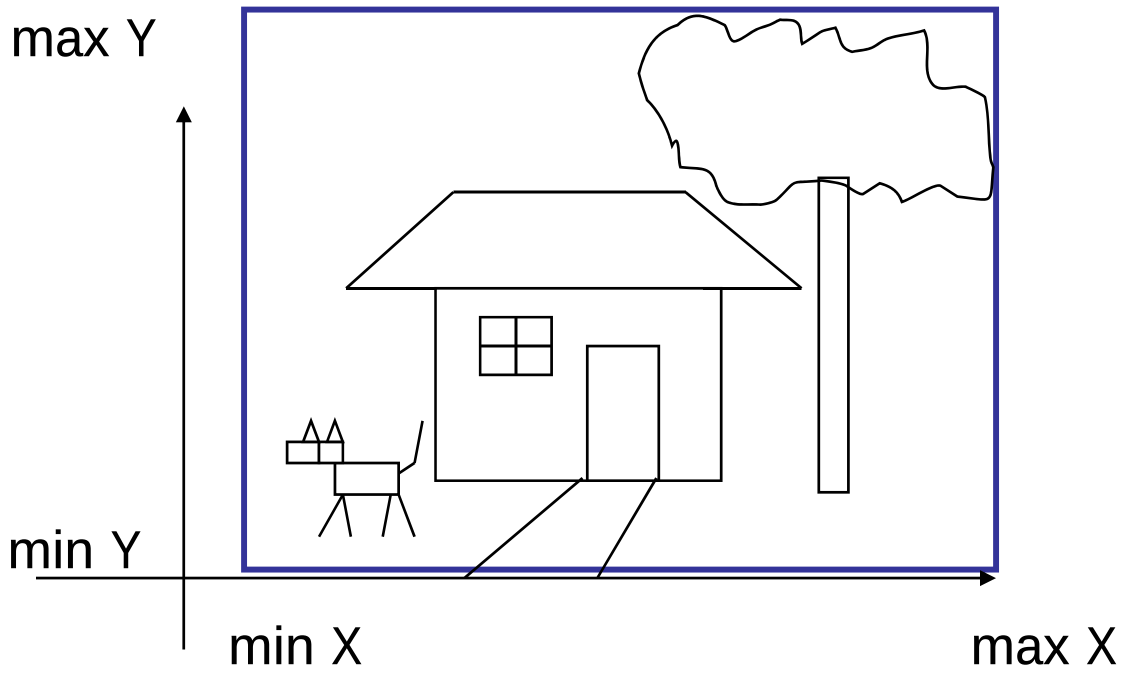
- How to set up an appropriate world window automatically?
- How to zoom in the picture?
- How to set up an appropriate viewport, so that the picture is not going to be distorted?

World window setup

- The basic idea is to see all the objects in the world
  - This can just be your initial view, and the user can change it later
- How to achieve it?

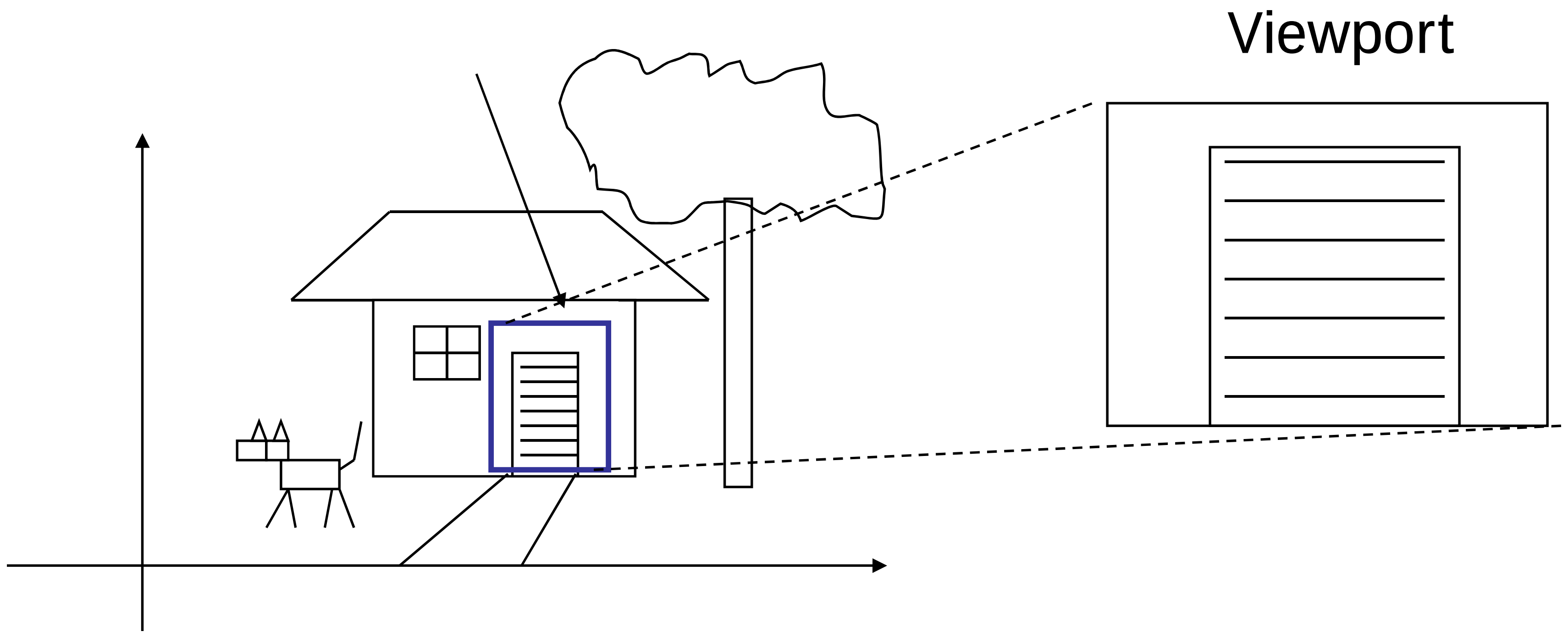
World window set up

- Find the world coordinates extent that will cover the entire scene



Zoom into the picture

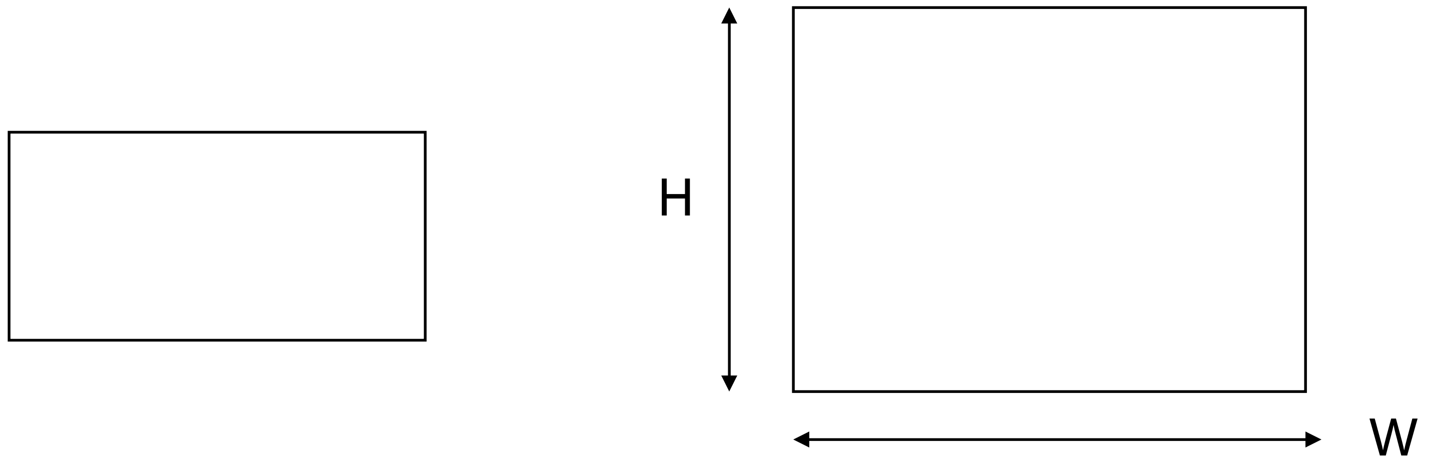
Shrink your world window – call gluOrtho2D() with a new range



Non-distorted viewport setup

- Distortion happens when ...
- World window and display window have different aspect ratios
- Aspect ratio?
- R = W / H

Compare aspect ratios



World window

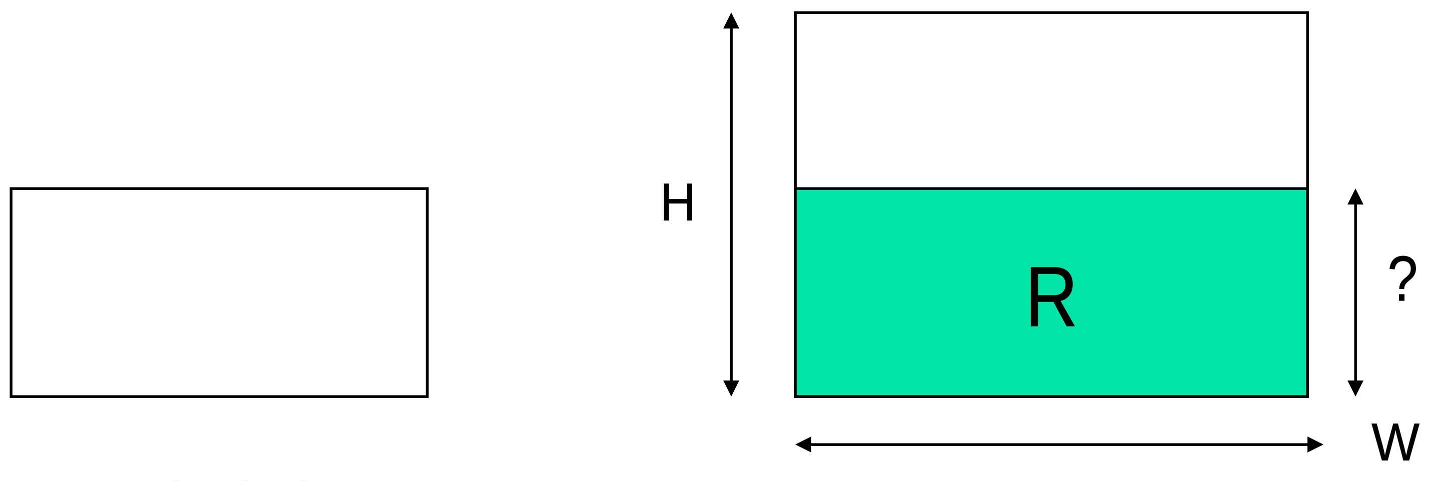
Aspect Ratio = R

Display window

Aspect Ratio = W / H

R > W / H

Match aspect ratios



World window

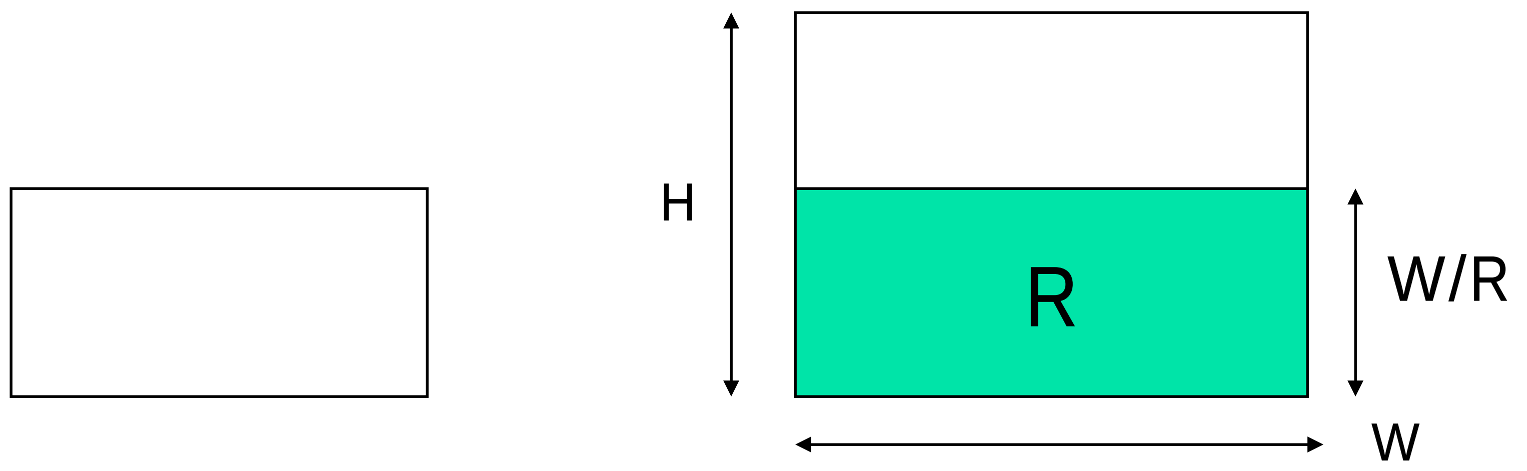
Aspect Ratio = R

Display window

Aspect Ratio = W / H

$$R > W / H$$

Match aspect ratios



World window

Aspect Ratio = R

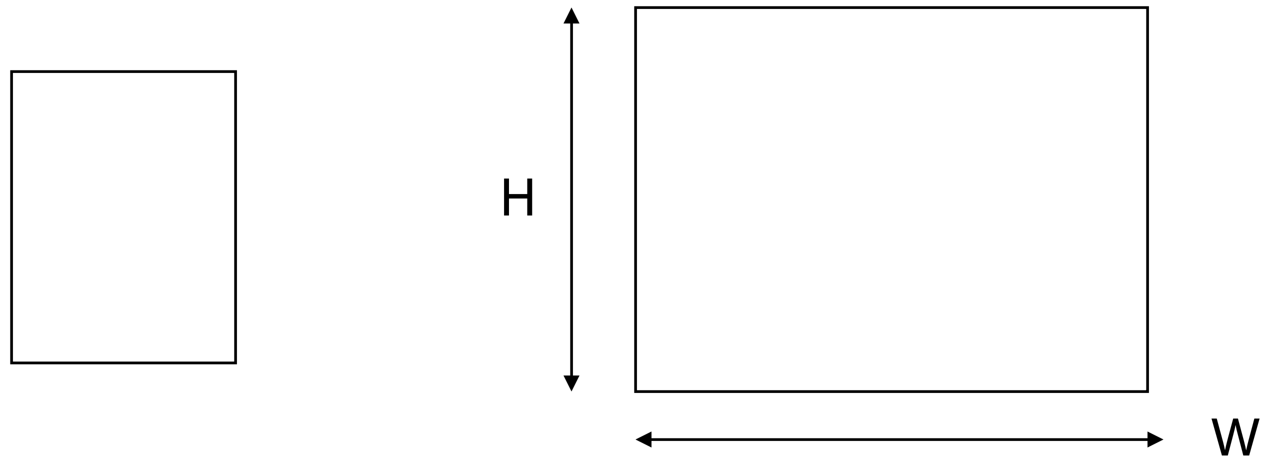
Display window

Aspect Ratio = W / H

$\boxed{R > W / H}$

glViewport(0, 0, W, W/R)

Compare aspect ratios



World window

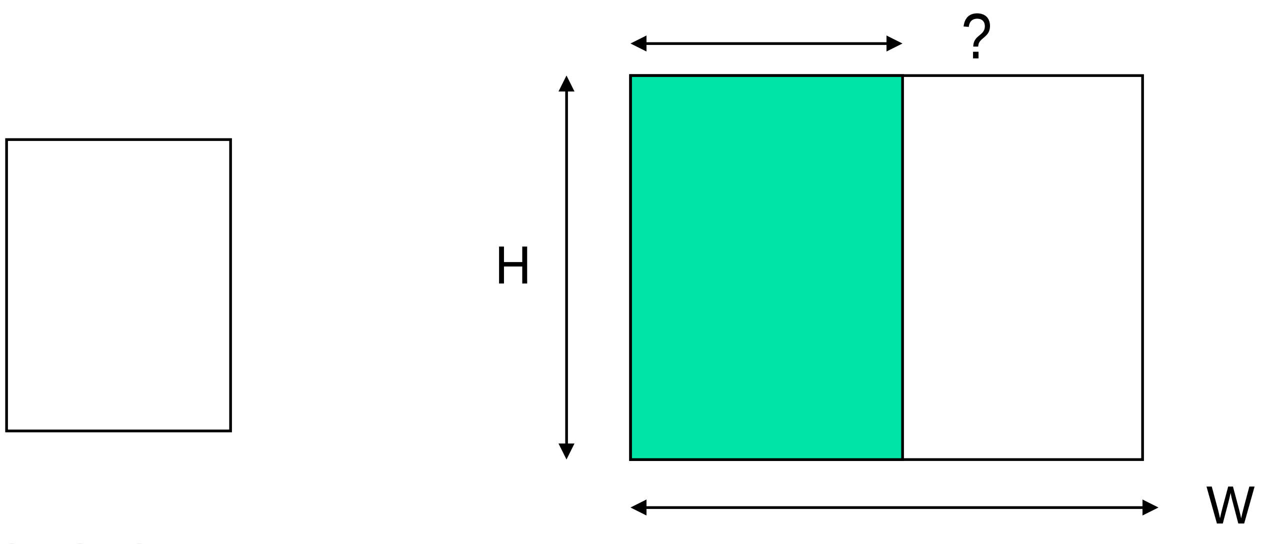
Aspect Ratio = R

Display window

Aspect Ratio = W / H

$$R < W / H$$

Match aspect ratios



World window

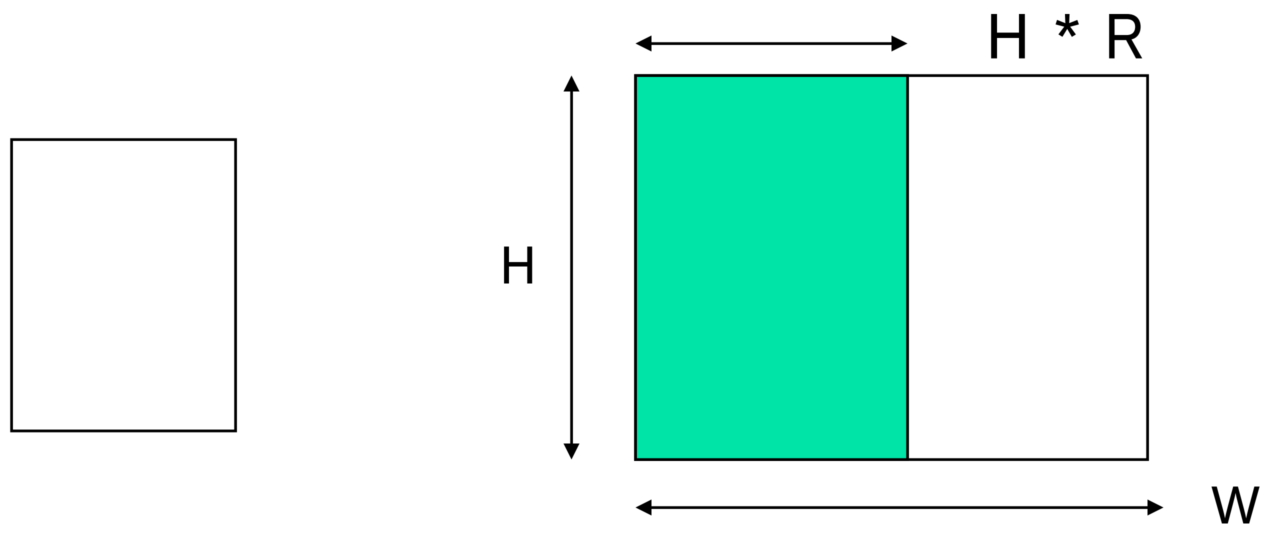
Aspect Ratio = R

Display window

Aspect Ratio = W / H

$$R < W / H$$

Match aspect ratios



World window

Aspect Ratio = R

Display window

Aspect Ratio = W / H

$\boxed{R < W / H}$

glViewport(0, 0, H*R, H)

When to call glViewport() ?

Two places:

- Initialization
  - Default: same as the window size
- When the user resizes the display window

Resize (Reshape) window

```
Void main(int argc, char** argv)
{
      ...
     glutDisplayFunc(display);
     glutReshapeFunc(resize);
     glutKeyboardFunc(key);
     …
}
```

void resize () – a function provided by you. It will be called when the window changes size.

Resize (reshape) window

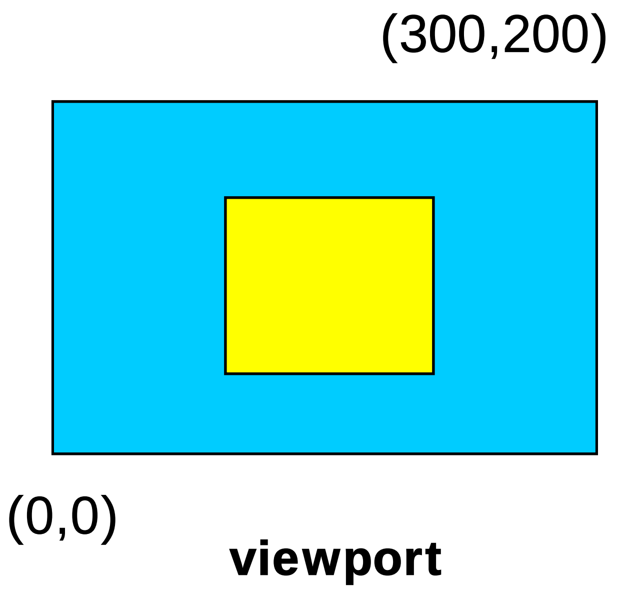
```
Void resize(int W, int H)
{
        glViewport(0,0,W, H);
}
```

This is done by default in GLUT

You can use the call to make sure the aspect ratio is fixed that we just discussed.

Put it all together

```
DrawQuad()
{
    glViewport(0,0,300,200);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(-1,1,-1,1);
    glBegin(GL_QUADS);
    glColor3f(1,1,0);
    glVertex2f(-0.5,-0.5);
    glVertex2f(+0.5,-0.5);
    glVertex2f(+0.5,+0.5);
    glVertex2f(-0.5,+0.5);
    glEnd();
}
```



How big is the quad?

Well, this works too ...

```
main()
{
…
    glBegin(GL_QUADS);
    glColor3f(1,1,0);
    glVertex2f(-0.5,-0.5);
    glVertex2f(+0.5,0);
    glVertex2f(+0.5,+0.5);
    glVertex2f(-0.5,+0.5);
    glEnd();
}
```

Why?

```
OpenGL Default:

glViewport: as large as
    you display window

gluOrtho2D:
    gluOrtho2D(-1,1,-1,1);
```

Every time you learn a new OpenGL function, always try to know its default arguments