Computer Graphics

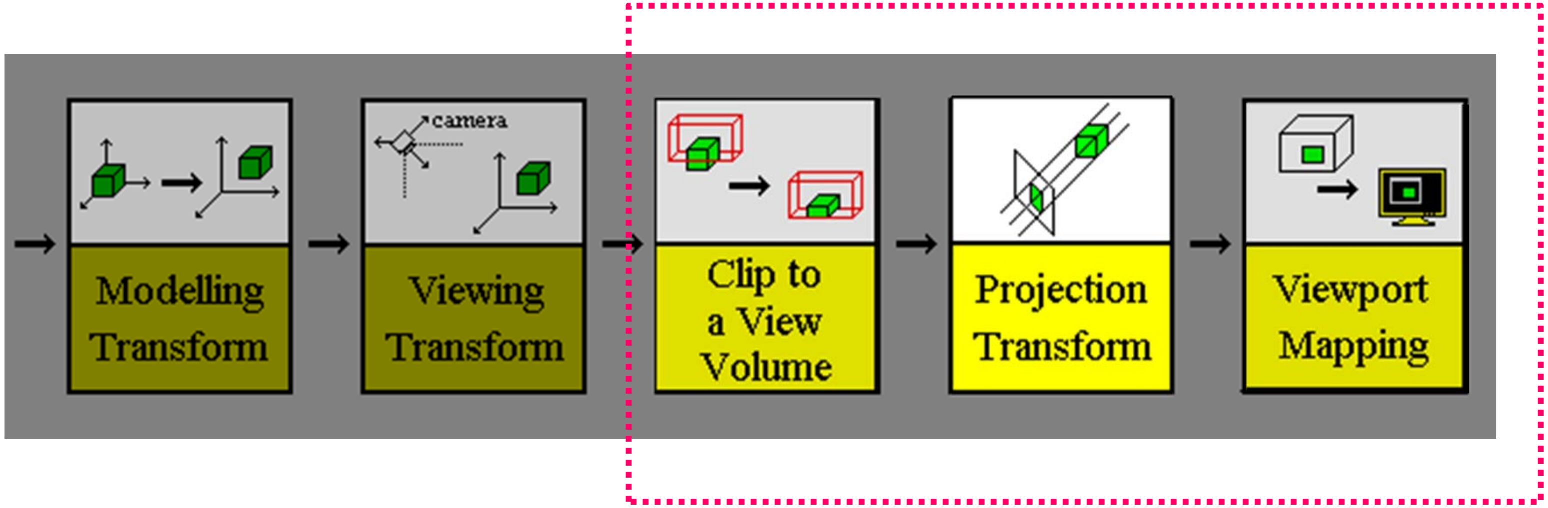
Chapter 8 (I)

Two - Dimensional Viewing

Outline

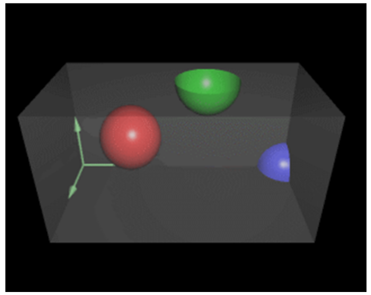
- Viewing Pipeline
- World Coordinates Transfer to Viewing Coordinates
- Normalization and Viewport Transformations
- OpenGL 2D Viewing Functions
- OpenGL 2D Viewing Program Example

Viewing Pipeline

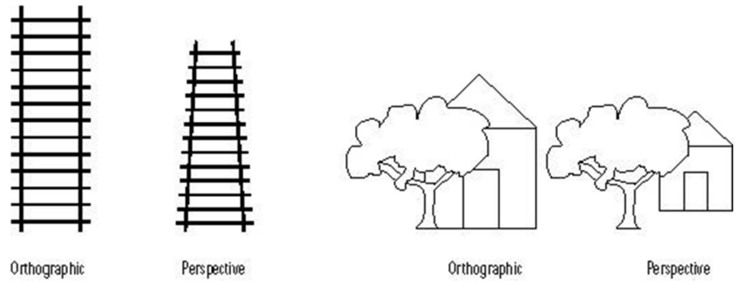


Viewing Volume

- Viewing volume
  - A closed volume which delimits the **infinite** 3D space to **finite** volume.
  - Points outside it will not appear on the screen.



- Two projections to create viewing volume
  - Orthographic projection
    - Objects rendered are not affected by the distance
    - E.g.: a menu, a text on a screen, 2D objects…
  - Perspective projection
    - Objects rendered are affected by the distance
    - E.g.: a car is seen smaller when it move away

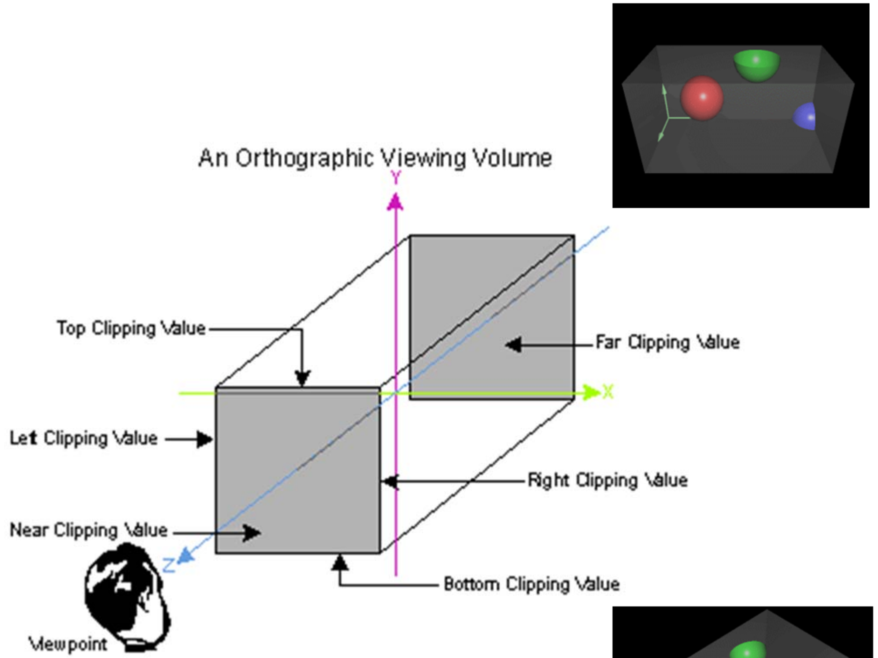


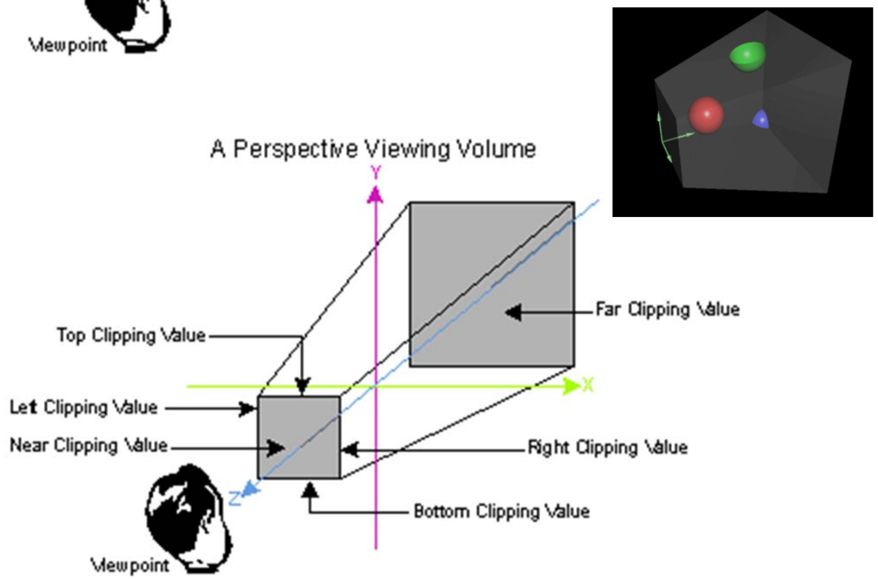
(From OpenGL Super Bible)

Viewing Volume

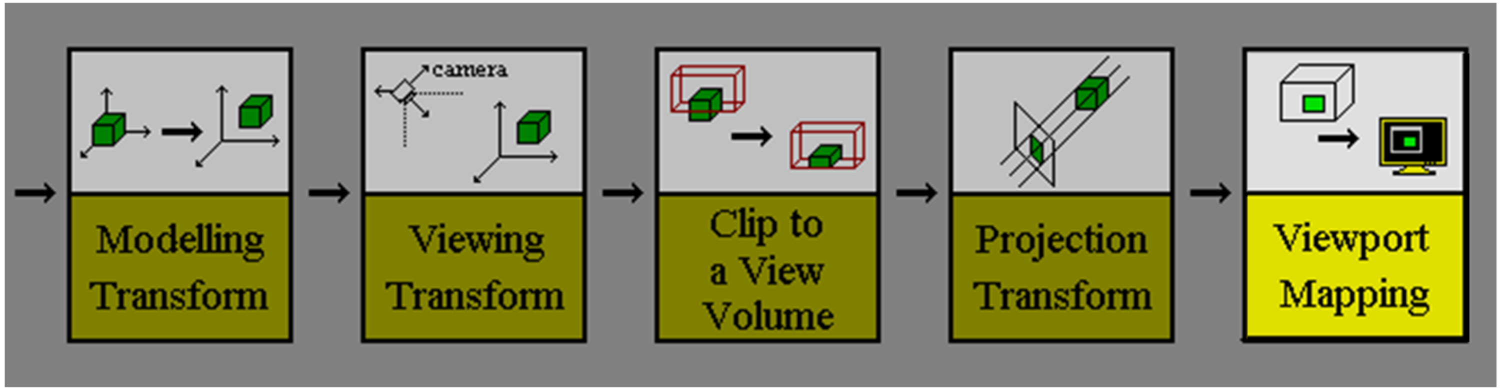
- Orthographic projection
  - Viewing volume shape is a parallelepiped(平行六面體).
  - Parallel clipping planes

- Perspective projection
  - Viewing volume shape is a truncated pyramid (its top is cut).
  - Non-parallel side clipping planes





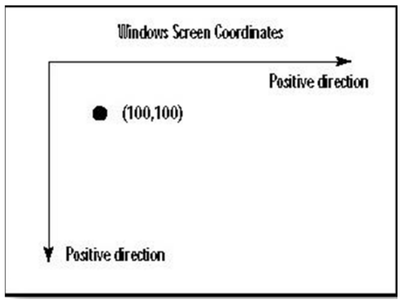
Viewport



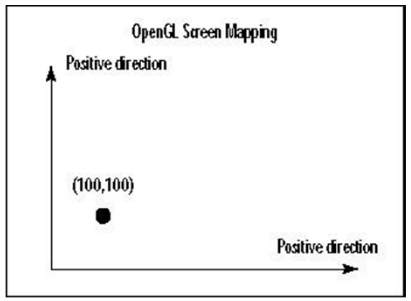
- Viewport
  - 2D drawing region of the screen where the final result is mapped.

Viewport

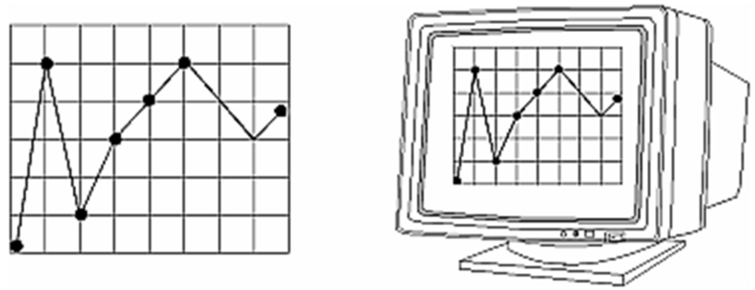
- Measured in actual window coordinates



Default Windows screen coordinate mapping



Default OpenGL window coordinate mapping



(From OpenGL Super Bible)

void **glViewport** (GLint *x*, GLint *y*, GLsizei *width*, GLsize *height*);

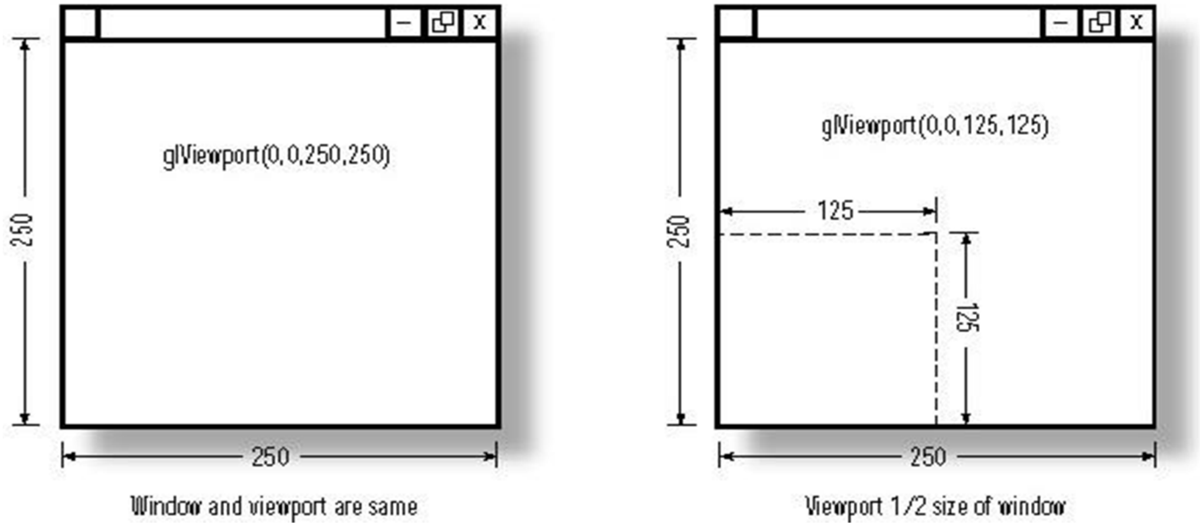
(*x, y*): specifies the lower-left corner of the viewport;

width and *height:* the size of the viewport rectangle.

By default, the initial viewport are ***(0, 0, winWidth, winHeight)***, where *winWidth* and *winHeight* are the size of the window.

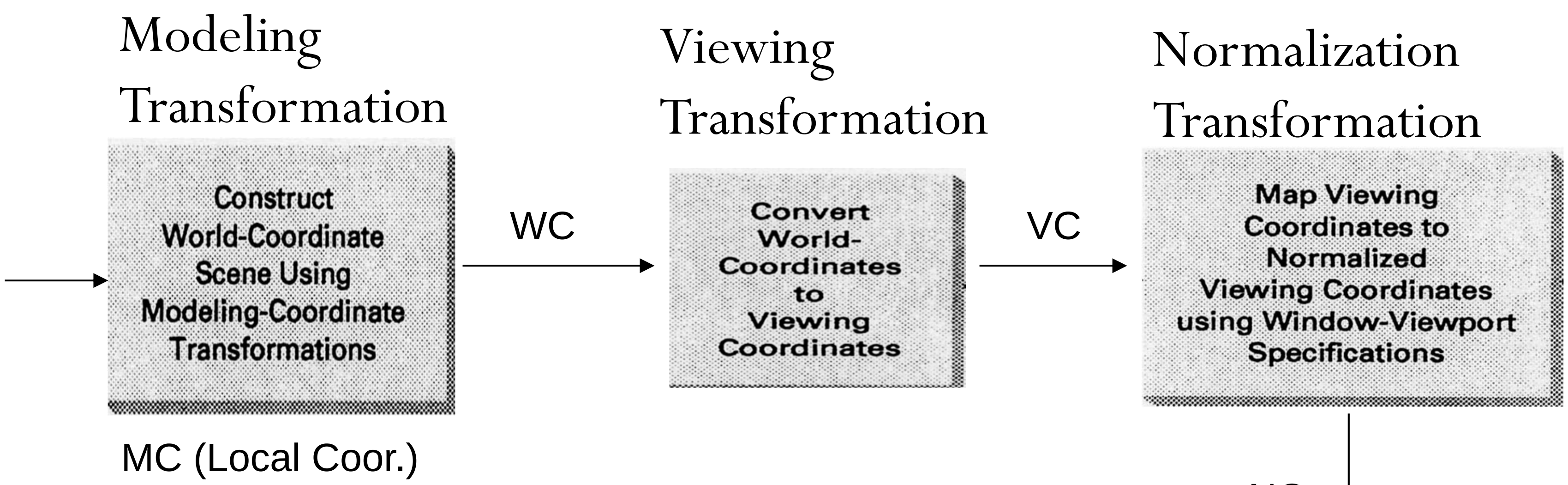
Viewport

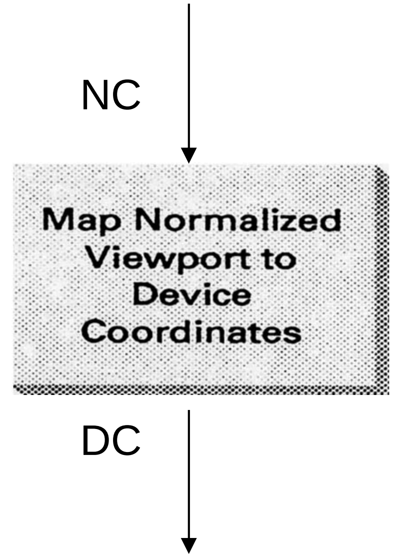
- Example



(*From OpenGL Super Bible*)

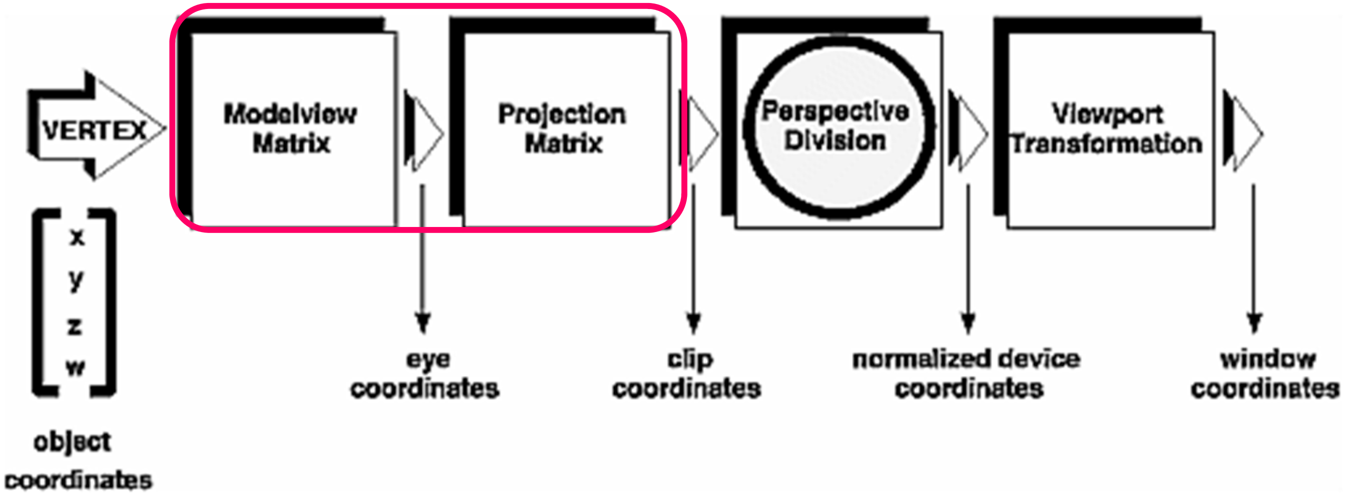
2D Viewing Pipeline





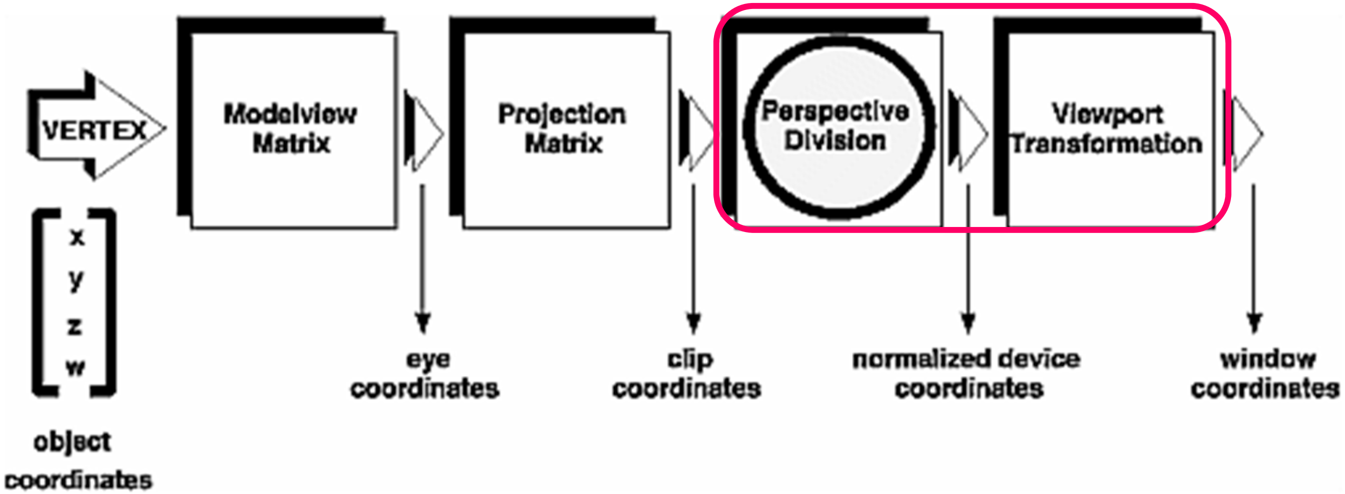
- To make the viewing process independent of any output device, viewing coordinates is converted to normalized coordinates.
- Clipping is usually performed in normalized coordinates.

Stages of Vertex Transformation



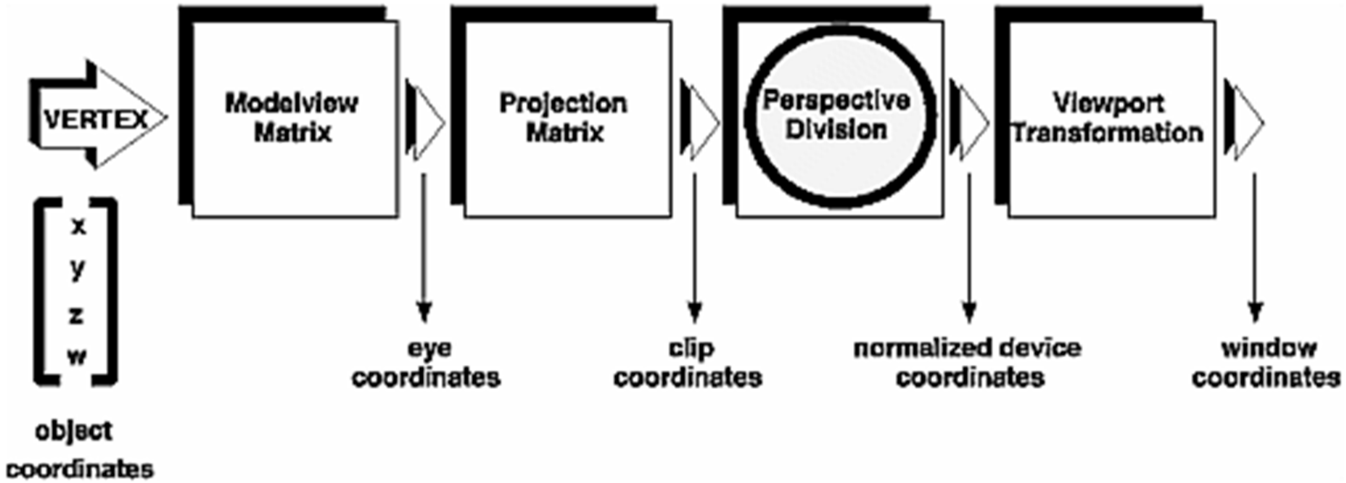
- Matrix-form in OpenGL
  - The **viewing** and **modeling** transformations you specify are combined to form the **modelview** matrix, which is applied to the incoming *object coordinates* to yield **eye (viewing) coordinates**.
  - The **projection** matrix to yield **clip coordinates**.
    - Defines a viewing volume

Stages of Vertex Transformation



- Matrix form in OpenGL (cont.)
  - The *perspective division* is performed by dividing coordinate values by *w*, to produce *normalized device coordinates*.
  - The transformed coordinates are converted to *window coordinates* by applying the viewport transformation.
    - You can specify the size of the viewport to cause the final image result.

Stages of Vertex Transformation



- The viewing, modeling, and projection transformations matrix in OpenGL: **4×4 matrix M** [in 2D, z = 0]
- They are multiplied by the coordinates of each vertex *v* in the scene

$$v' = Mv$$

World Coordinates Convert to Viewing Coordinates

We can set up a 2D viewing coordinate system in the world coordinate frame.

(x_0, y_0): an origin

yview: 2D view up vector

This viewing coordinate frame provides a reference for specifying the clipping window.

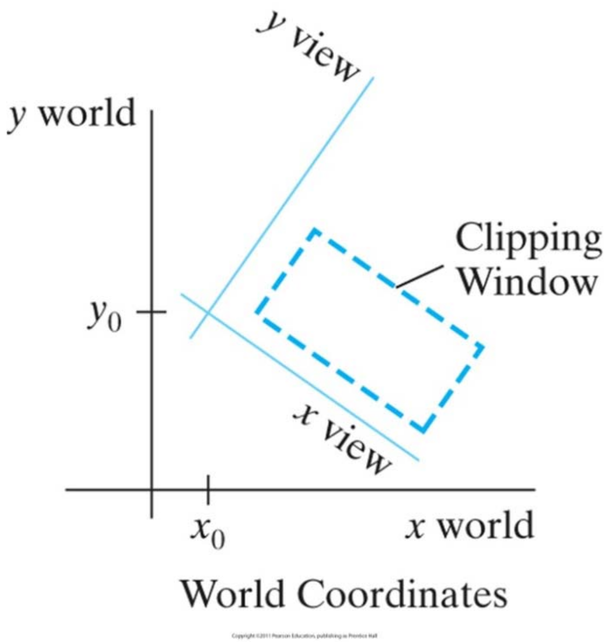
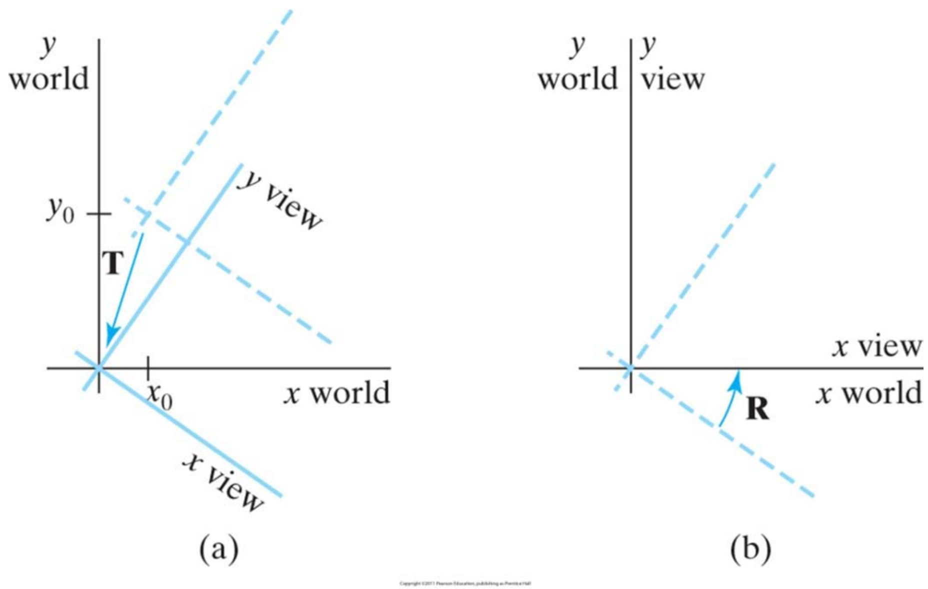


Fig. 8-3 A rotated world window in *Viewing Coordinates*.

World Coordinates Convert to Viewing Coordinates



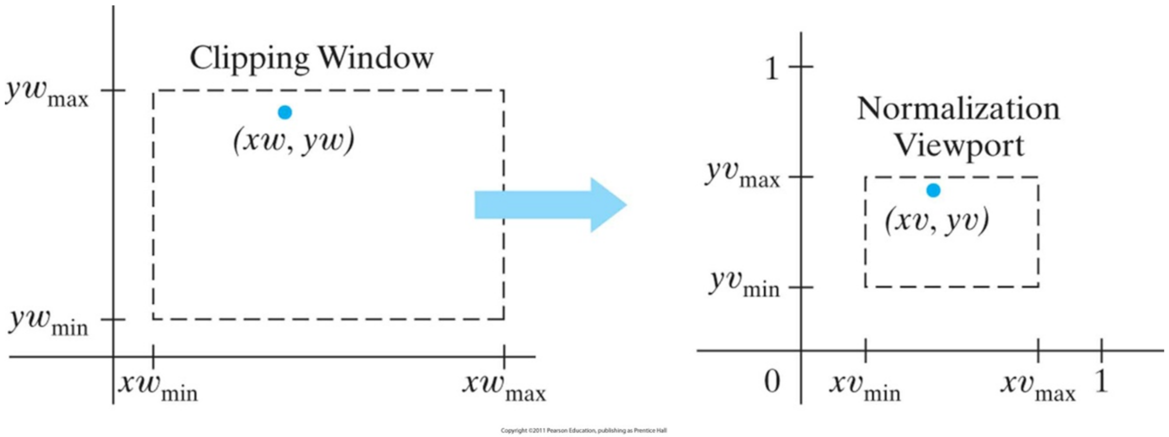
$$\mathbf{M}_{wc\text{->}vc} = \mathbf{R} \bullet \mathbf{T} \qquad \textbf{(8-1)}$$

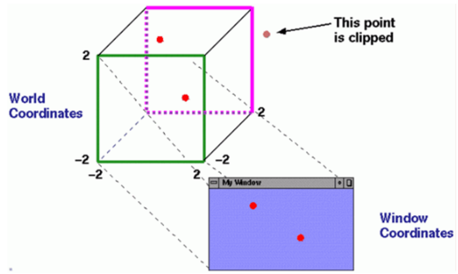
Where **T** is the translation matrix that takes the viewing origin point P_0 to the world origin, and **R** is the rotation matrix that aligns the axes of the two reference frames

FIGURE 8-4 A *Viewing-Coordinate* frame is moved into coincidence with the *World - Coordinate* frame by
(a) applying a **translation** matrix **T** to move the viewing origin to the world origin, then
(b) applying a **rotation** matrix **R** to align the axes of the two systems.

Normalization and Viewport Transformations

- Mapping a clipping window into a normalized viewport (the viewport is given within ([0,1], [0,1]))





$$\frac{xv - xv_{min}}{xv_{max} - xv_{min}} = \frac{xw - xw_{min}}{xw_{max} - xw_{min}}$$

$$\frac{yv - yv_{min}}{yv_{max} - yv_{min}} = \frac{yw - yw_{min}}{yw_{max} - yw_{min}}$$

FIGURE 8-6 A point (xw, yw) in a world-coordinate clipping window is mapped to viewport coordinates (xv, yv), within a unit square, so that the relative positions of the two points in their respective rectangles are the same.

OpenGL 2D Viewing Functions

- OpenGL Projection Mode

  glMatrixMode (GL_PROJECTION); //projection matrix
  glLoadIdentity ();

- GLU Clipping-Window Function

  gluOrtho2D (xwmin, xwmax, ywmin, ywmax);
  2D parallel projection.

- OpenGL Viewport Function

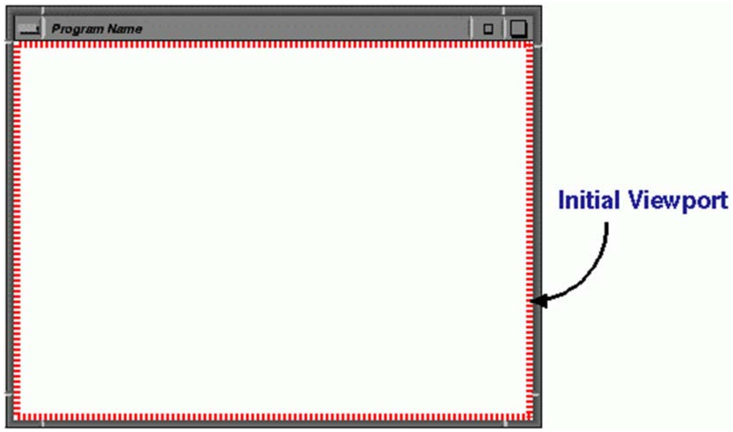
  glViewport (xvmin, yvmin, vpWidth, vpHeight);

  glGetIntegerv (GL_VIEWPORT, vpArray);

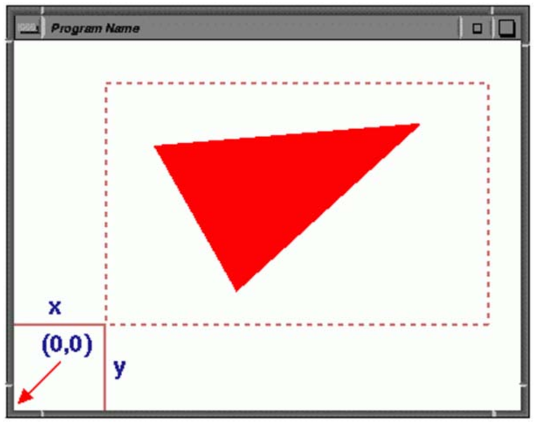
  To obtain the parameters for the currently active viewport: xvmin, yvmin, vpWidth, vpHeight.

OpenGL Viewport Function

- glViewport (GLint x, GLint y, GLsizei width, Glsizei height);



You can change it by glViewport().

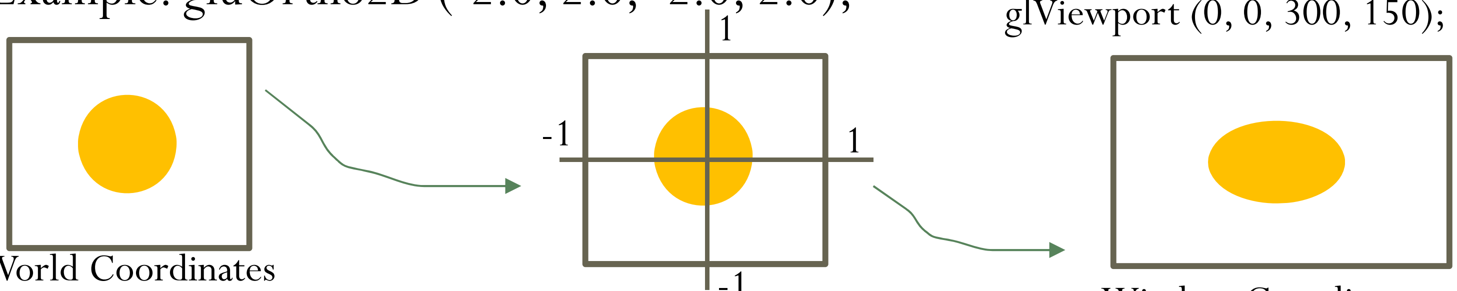


Always rectangle;

x, y are in window coordinates

- Example: gluOrtho2D (-2.0, 2.0, -2.0, 2.0);

glViewport (0, 0, 300, 150);



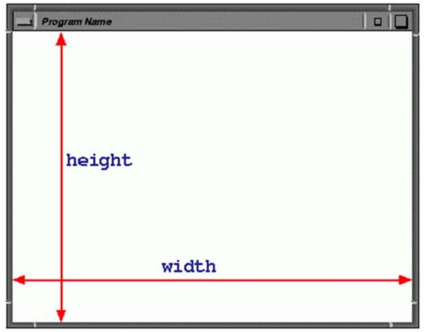
World Coordinates

Normalized Device Coordinates

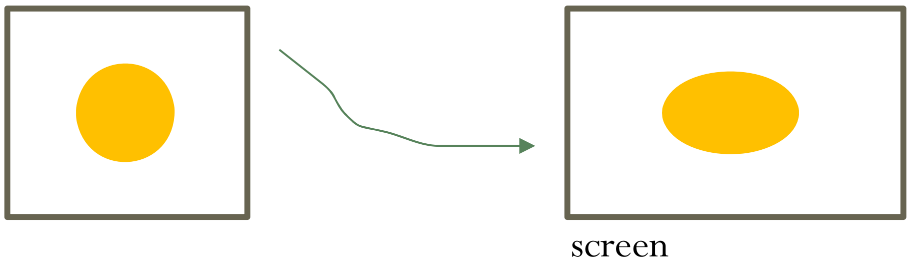
Window Coordinates

OpenGL Viewport Function

- The rectangle area has an aspect ratio: width / height
  - Windows
    - glutInitWindowSize (width, height);
  - 2D clipping window
    - gluOrtho2D (left, right, bottom, top);
  - Viewport
    - glViewport (x, y, width, height);



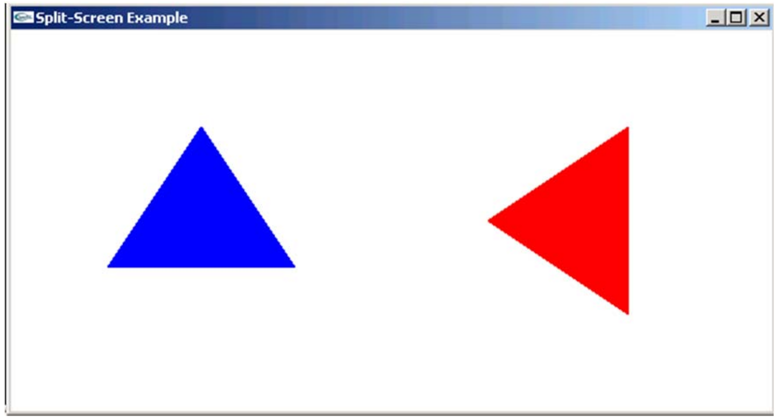
- In general, the clipping window (viewing volume) and viewport need to have the same ratio.



OpenGL 2D Viewing Program Example

- Two views of a triangle in the xy plane shown in a split screen, with its centroid at the world-coordinate origin

```
#include <GL/glut.h>
class wcPt2D
{
public:
        GLfloat x, y;
};
```



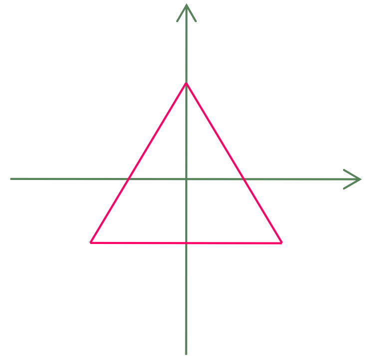
OpenGL 2D Viewing Program Example

```
void init (void)
{
  /*  Set color of display window to white.  */
  glClearColor (1.0, 1.0, 1.0, 0.0);

  /*  Set parameters for world-coordinate clipping window.  */
  glMatrixMode (GL_PROJECTION);
  gluOrtho2D (-100.0, 100.0, -100.0, 100.0);

  /*  Set mode for construction geometric transformation matrix.  */
  glMatrixMode (GL_MODELVIEW);
}
```

OpenGL 2D Viewing Program Example

```
void triangle (wcPt2D *verts)
{
   GLint k;

   glBegin (GL_TRIANGLES);
      for (k =0; k < 3; k++)
                  glVertex2f (verts [k].x, verts [k].y);
       glEnd ();
}
```

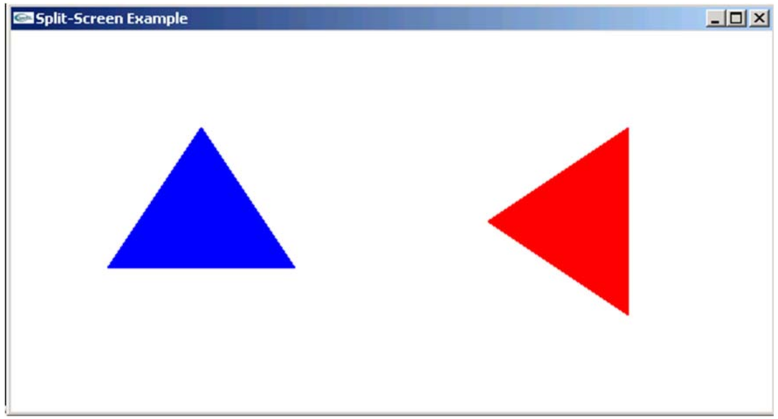
OpenGL 2D Viewing Program Example



```
void displayFcn (void)
{
    /*  Define initial position for triangle.  */
    wcPt2D verts [3] = {{-50.0, -25.0}, {50.0, -25.0}, {0.0, 50.0}};

    glClear (GL_COLOR_BUFFER_BIT);     // Clear display window.

    glColor3f (0.0, 0.0, 1.0);         // Set fill color to blue.
    glViewport (0, 0, 300, 300);       // Set left viewport.
    triangle (verts);                  // Display red rotated triangle.

    /*  Rotate triangle and display in right half of display window.  */
    glColor3f (1.0, 0.0, 0.0);         // Set fill color to red.
    glViewport (300, 0, 300, 300);     // Set right viewport.
    glRotatef (90.0, 0.0, 0.0, 1.0);   // Rotate about z axis.
    triangle (verts);                  // Display red rotated triangle.

    glFlush (); //Force to execute all OpenGL functions
}
```

OpenGL 2D Viewing Program Example

```
void main (int argc, char **argv)
{
   glutInit (&argc, argv);
   glutInitDisplayMode (GLUT_SINGLE | GLUT_RGB);
   glutInitWindowPosition (50, 50);
   glutInitWindowSize (600, 300);
   glutCreateWindow ("Split-Screen Example");

   init();
   glutDisplayFunc (displayFcn);
   glutMainLoop ();
}
```



OpenGL 2D Viewing Functions

- You need to handle the changes in the window size
  - Registering a window reshape callback
    - void glutReshapeFunc (void (*func) (int width, int height));
  - Defining the reshape callback function: pass the new width and height of the window
    - called before the first call to the display function,
    - and called automatically when the window is reshaped.
    - e.g. MyReshape ();

```
void MyReshape ( int width, int height )
{
    /* update viewport */
    glViewport (…);
    /* reset viewing volume */
    glMatrixMode ( GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D (…);
    /* set modelview matrix mode
    …
}
```

Summary

- 2D viewing pipeline
- OpenGL 2D viewing functions