CS 402:
Computer Graphics

Lecture Notes 05:

2D Viewing

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CS402: Computer Graphics

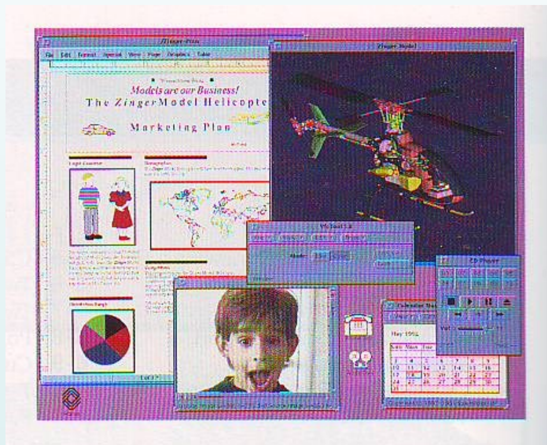
Two-Dimensional (2D) Viewing

- The 2-D Viewing Pipeline:
  - Transformation: world → Screen
- The Clipping Window
- Normalization and Viewport Transformation
- OpenGL 2-D Viewing Functions

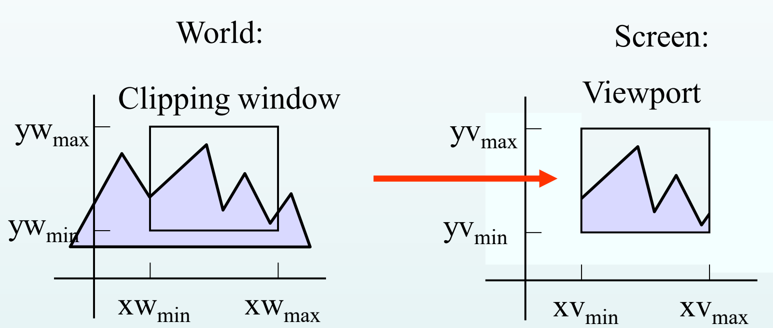
- Readings: 2D (Chapter 6).

2D Viewing

- **Every thing is displayed on a 2D screen**



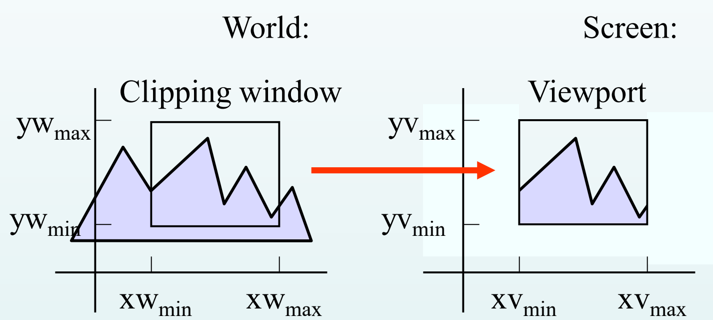
2D Viewing



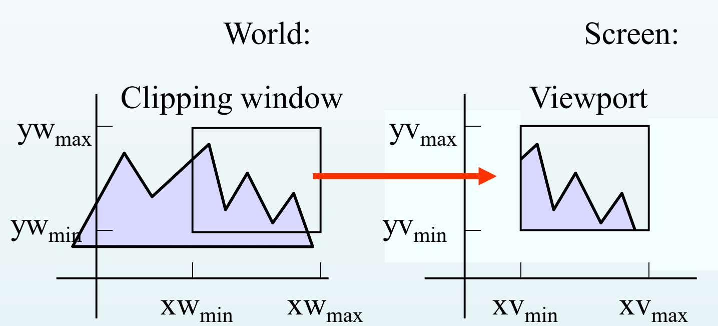
Clipping window:
What do we want to see?

Viewport:
Where do we want to see it?

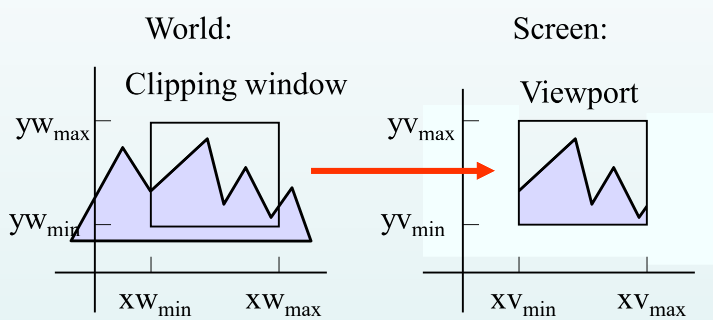
2D Viewing: Panning



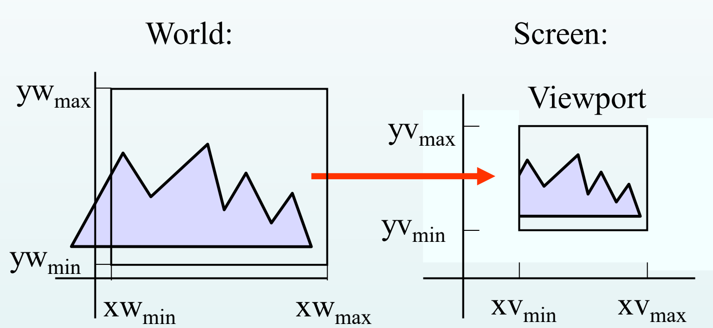
2D Viewing: Panning



2D Viewing: Zooming

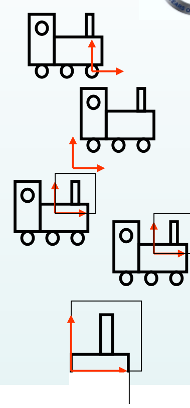


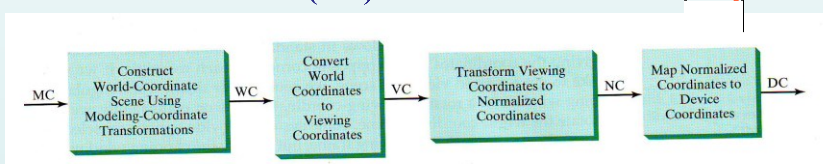
2D Viewing: Zooming



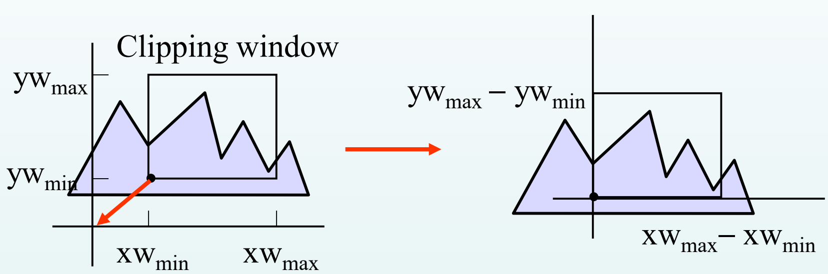
2D Viewing Pipeline

- **Modeling Coordinates (MC):**
  - **Apply model transformations**
- **World Coordinates (WC):**
  - **Determine visible parts**
- **Viewing Coordinates (VC):**
  - **To standard coordinates**
- **Normalized Coordinates (NC):**
  - **Clip and determine pixels**
- **Device Coordinates (DC):**



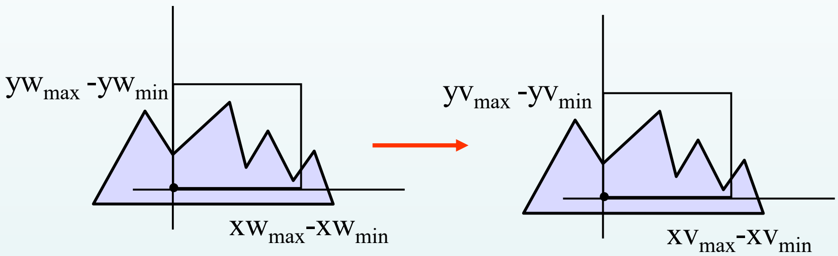


Clipping Window



- **Clipping window usually an axis-aligned rectangle**
- **Sometimes rotation**
- **From world to view coordinates:** $\mathbf{T}(-xw_{\min}, -yw_{\min})$
- **possibly followed by rotation**
- **More complex in 3D**

To Normalized Coordinates

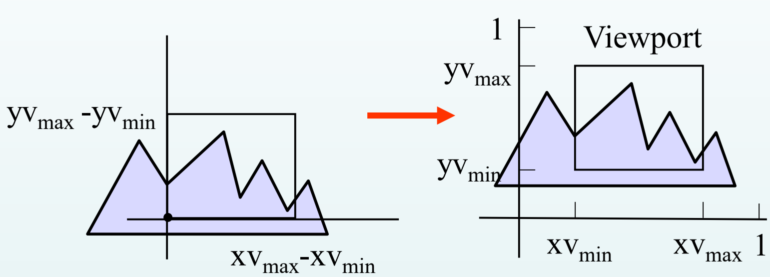


Scale with:

$$\mathbf{S}\left(\frac{xv_{\max}-xv_{\min}}{xw_{\max}-xw_{\min}},\frac{yv_{\max}-yv_{\min}}{yw_{\max}-yw_{\min}}\right)$$

If the two scale factors are equal, then the aspect ration changes: distortion.

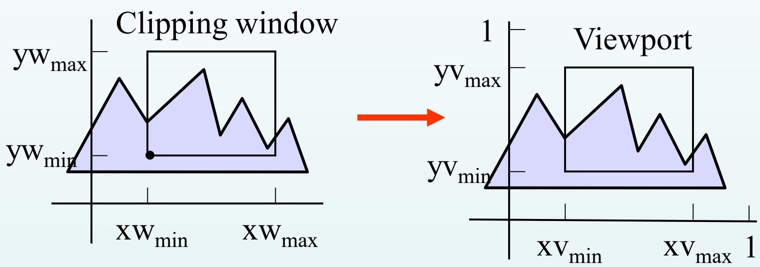
To Normalized Coordinates



Translate with:

$$\mathbf{T}\left(xv_{\min}, yv_{\min}\right)$$

To Normalized Coordinates



All together

$$\mathbf{T}(xv_{\min}, yv_{\min})\mathbf{S}\left(\frac{xv_{\max} - xv_{\min}}{xw_{\max} - xw_{\min}}, \frac{yv_{\max} - yv_{\min}}{yw_{\max} - yw_{\min}}\right)\mathbf{T}(-xw_{\min}, -yw_{\min})$$

2D Viewing: Rotation

Rotation

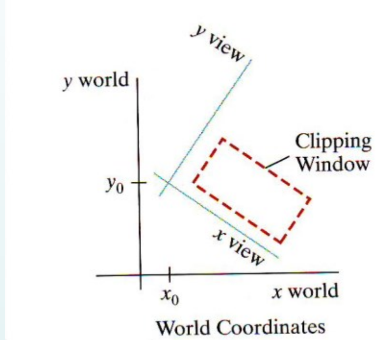
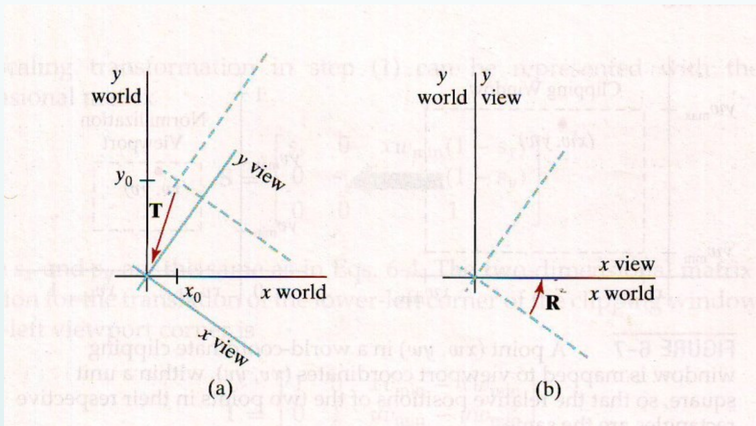


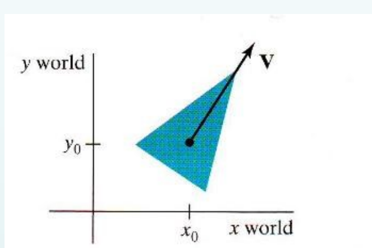
FIGURE 6-4 A rotated clipping window defined in viewing coordinates.

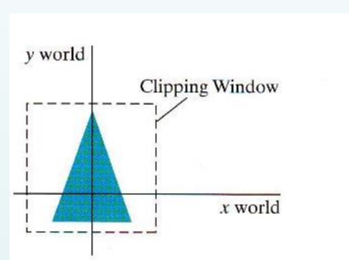
2D Viewing: Rotation & Transformation



$M_{WC,VC} = R.T$

2D Viewing: Rotation & Transformation





World to Normalized Viewport

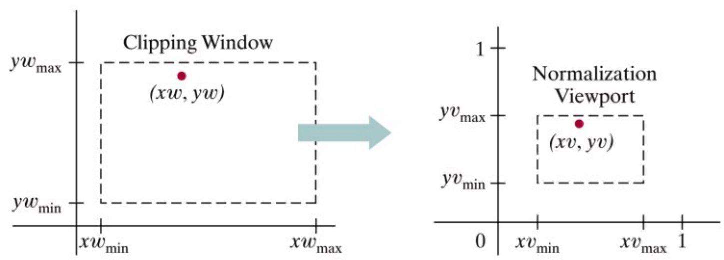


Figure 6-7

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.

World to Normalized Viewport

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

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

$$xv = s_x xw + t_x$$

$$yv = s_y yw + t_y$$

$$t_x = \frac{xw_{\max} xv_{\min} - xw_{\min} xv_{\max}}{xw_{\max} - xw_{\min}}$$

$$t_y = \frac{yw_{\max} yv_{\min} - yw_{\min} yv_{\max}}{yw_{\max} - yw_{\min}}$$

$$s_x = \frac{xv_{\max} - xv_{\min}}{xw_{\max} - xw_{\min}}$$

$$s_y = \frac{yv_{\max} - yv_{\min}}{yw_{\max} - yw_{\min}}$$

World to Normalized Viewport

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & xv_{\text{min}} - xw_{\text{min}} \\ 0 & 1 & yv_{\text{min}} - yw_{\text{min}} \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{S} = \begin{bmatrix} s_x & 0 & xw_{\text{min}}(1 - s_x) \\ 0 & s_y & yw_{\text{min}}(1 - s_y) \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{M}_{\text{window, normviewp}} = \mathbf{T} \cdot \mathbf{S} = \begin{bmatrix} s_x & 0 & t_x \\ 0 & s_y & t_y \\ 0 & 0 & 1 \end{bmatrix}$$

World to Normalized to Screen

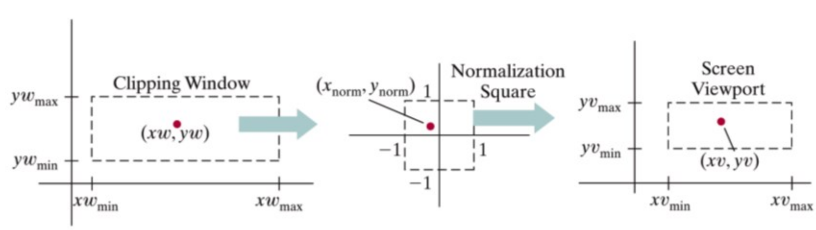


Figure 6-8

A point (xw, yw) in a clipping window is mapped to a normalized coordinate position (x_{norm}, y_{norm}), then to a screen-coordinate position (xv, yv) in a viewport. Objects are clipped against the normalization square before the transformation to viewport coordinates.

World to Normalized to Screen

$$\mathbf{M}_{\text{normsquare, viewport}} = \begin{bmatrix} \frac{xv_{\max} - xv_{\min}}{2} & 0 & \frac{xv_{\max} + xv_{\min}}{2} \\ 0 & \frac{yv_{\max} - yv_{\min}}{2} & \frac{yv_{\max} + yv_{\min}}{2} \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{M}_{\text{window, normsquare}} = \begin{bmatrix} \frac{2}{xw_{\max} - xw_{\min}} & 0 & -\frac{xw_{\max} + xw_{\min}}{xw_{\max} - xw_{\min}} \\ 0 & \frac{2}{yw_{\max} - yw_{\min}} & -\frac{yw_{\max} + yw_{\min}}{yw_{\max} - yw_{\min}} \\ 0 & 0 & 1 \end{bmatrix}$$

World to Normalized to Screen

An Example

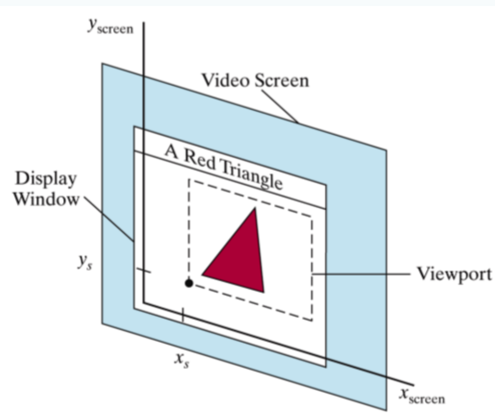


Figure 6-9

A viewport at coordinate position (x_s, y_s) within a display window.

Next Time

Primitive Drawing Algorithms