Computer Graphics

2D Viewing & Clipping

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Lecture Outlines

- Coordinate Systems
- 2D Viewing Transformation
- Window to Viewport Mapping

Coordinate Systems

- **Cartesian** – along the x and y axis from (0,0).
- **Polar** – rotation around the angle θ e.g. (r, θ).
- Graphic libraries mostly uses Cartesian coordinates.
- Any polar coordinates must be converted to Cartesian coordinates.
- Four Cartesian coordinates systems in computer Graphics:
    1. Modeling coordinates;
    2. World coordinates;
    3. Normalized device coordinates;
    4. Device coordinates.

Modeling Coordinates

- A coordinate system used for three-dimensional modeling in which each object possesses its own set of coordinates which can then be converted to a set of world coordinates.
- Also known as local coordinate.
- Each object has an origin (0,0).
- So the part of the objects are placed with reference to the object’s origin.
- In terms of scale it is user defined; so coordinate values can be any size.

World Coordinates

- The world coordinate system describes the relative positions and orientations of every generated objects.
- The scene has an origin (0,0).
- The object in the scene are placed with reference to the scenes origin.
- World coordinate scale may be the same as the modeling coordinate scale or it may be different.
- However, the coordinates values can be any size (similar to MC).

Normalized Device Coordinates

- Output devices have their own coordinates.

Coordinate values:

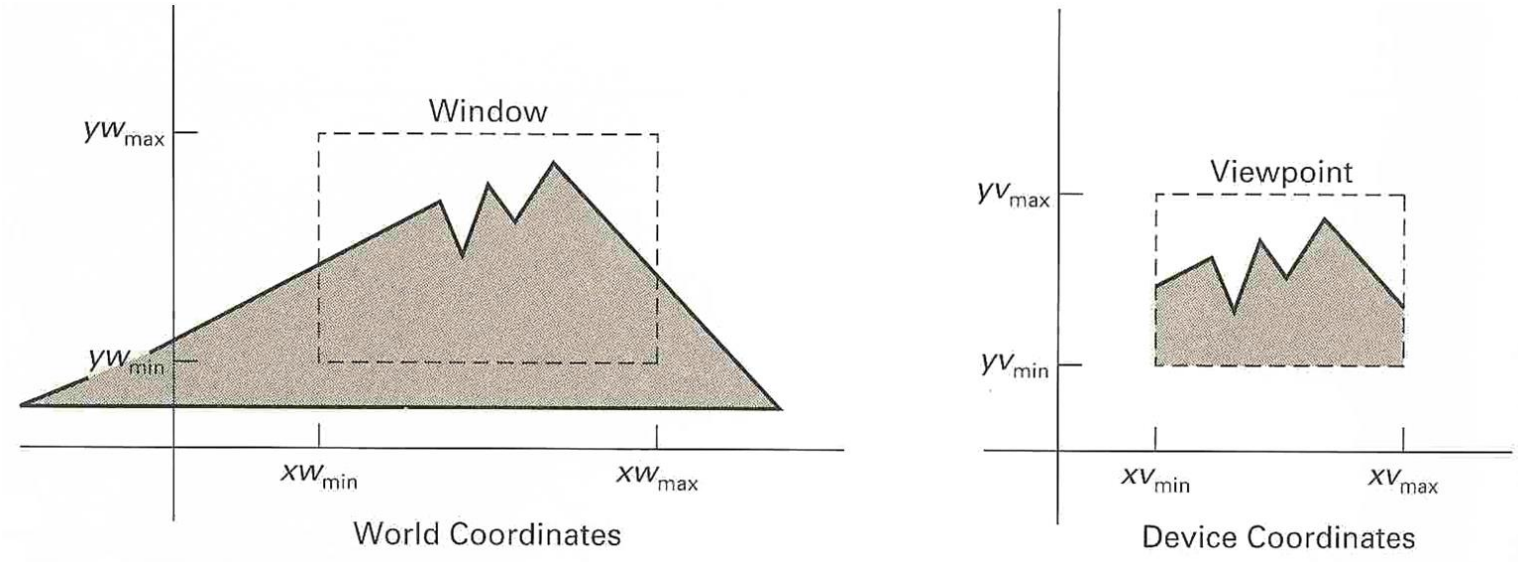
- The x and y axis range from 0 to 1.
- All the x and y coordinates are floating point numbers in the range of 0 to 1.
- This makes the system independent of the various devices coordinates.
- This is handled internally by graphic system without user awareness.

Device Coordinates

- Specific coordinates used by a device.
    - Pixels on a monitor
    - Points on a laser printer.
    - mm on a plotter.
- The transformation based on the individual device is handled by computer system without user concern.

2D Viewing Transformation

- The mapping of a part of a world-coordinate scene to device coordinates.
- 2D viewing transformation = window-to-viewport, windowing transformation.



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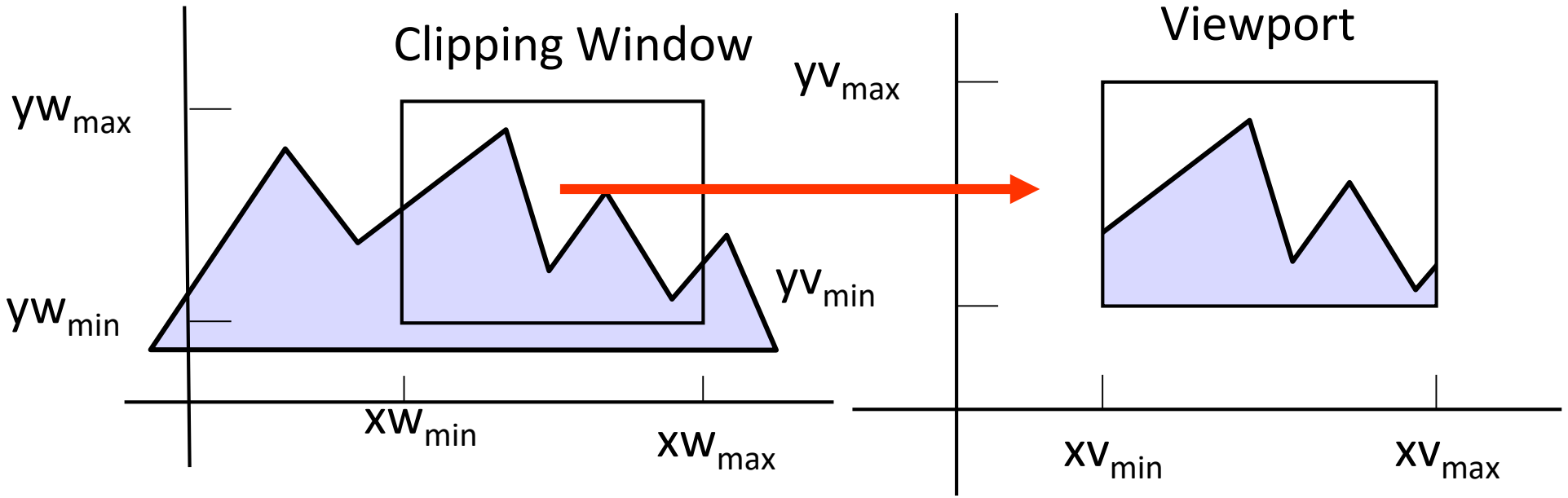
- **window**
  - a world-coordinate area selected for display.
  - define what is to be viewed.
- **view port**
  - an area on a display device to which a window is mapped.
  - define where it is to be displayed.
  - define within the unit square.
  - the unit square is mapped to the display area for the particular output device in use at that time.
- **windows & viewport**
  - be rectangles in standard position, with the rectangle edges parallel to the coordinate axes.

2D Viewing Transformation Steps

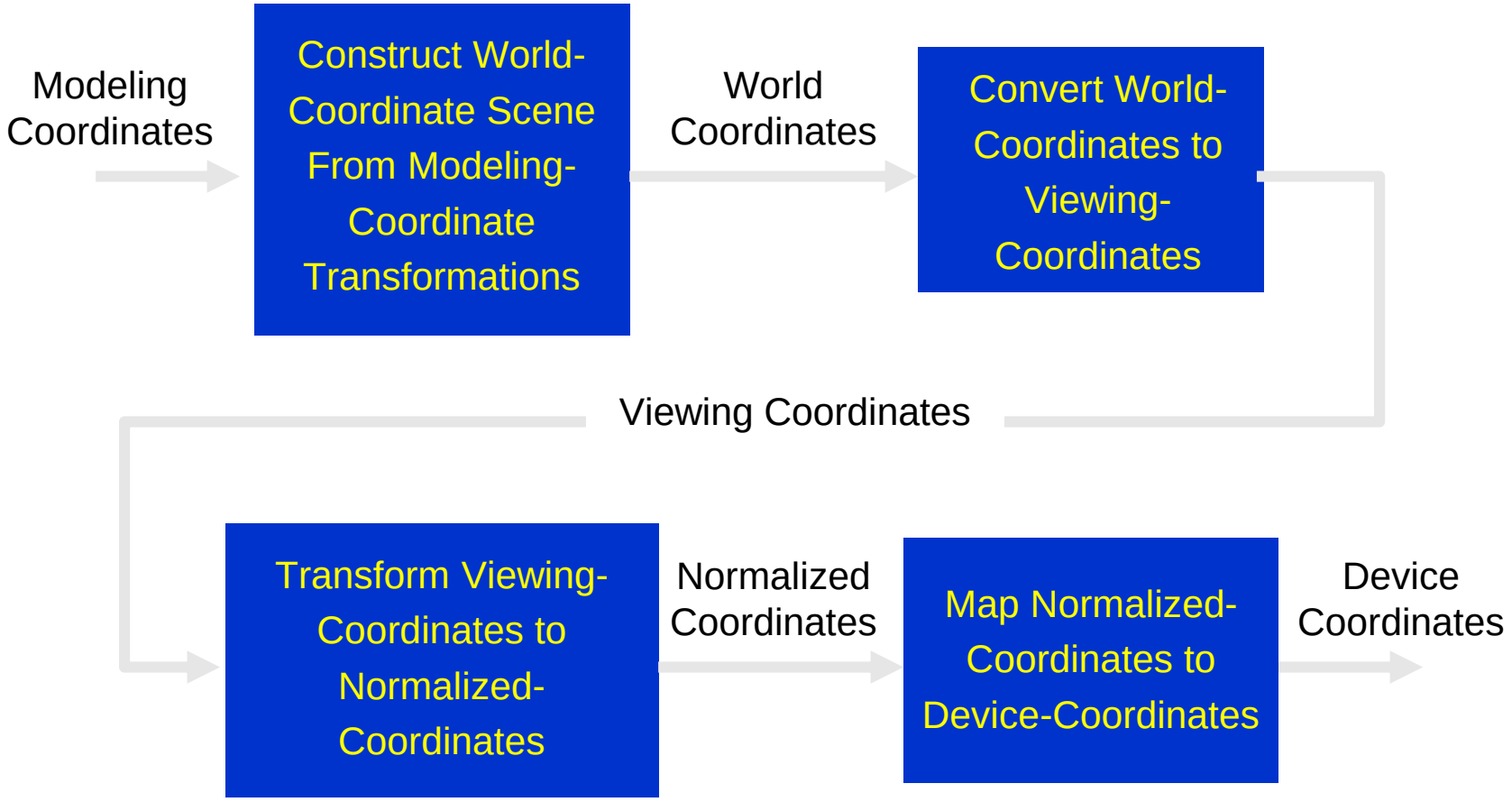
1. Construct the world-coordinate scene.
2. Transform descriptions in world coordinates to viewing coordinates.
3. Map the viewing-coordinate description of the scene to normalized coordinates.
4. Transfer to device coordinates.

Example


Clipping Window
Viewport
yw_{max}
yw_{min}
yv_{max}
yv_{min}
xw_{min}
xw_{max}
xv_{min}
xv_{max}
World Coordinate
Device Coordinate

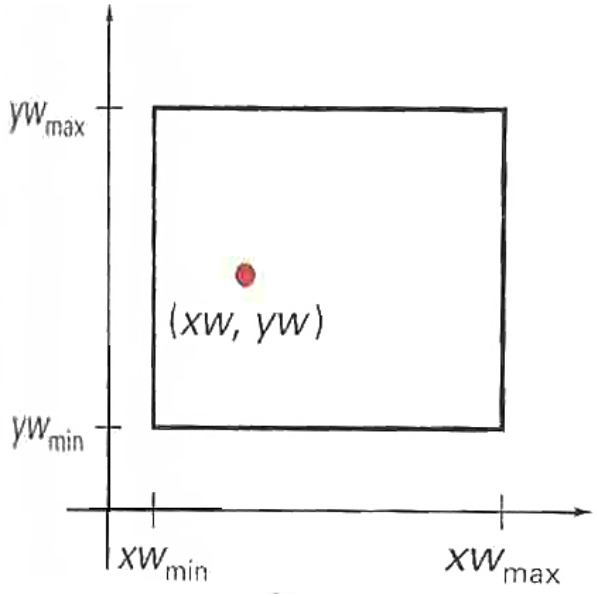
Viewing Transformation Pipeline

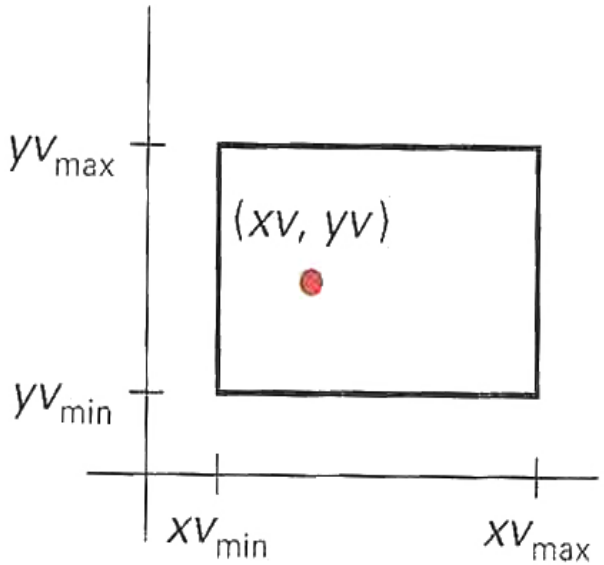
- The two-dimensional viewing-transformation pipeline



Window to Viewport Mapping

A point at position (xw, yw) in a designated window is mapped to viewport coordinates (xv, yv) so that relative positions in the two areas are the same.





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In order to maintain the same relative placement of the point in the viewport as in the window, we require:

$$\frac{xv - xv_{\min}}{xv_{\max} - xv_{\min}} = \frac{xw - xw_{\min}}{xw_{\max} - xw_{\min}} \quad \text{and} \quad \frac{yv - yv_{\min}}{yv_{\max} - yv_{\min}} = \frac{yw - yw_{\min}}{yw_{\max} - yw_{\min}}$$

Thus-

$$xv = xv_{\min} + (xw - xw_{\min})sx$$
$$yv = yv_{\min} + (yw - yw_{\min})sy$$

where

$$sx = \frac{xv_{\max} - xv_{\min}}{xw_{\max} - xw_{\min}}$$
$$sy = \frac{yv_{\max} - yv_{\min}}{yw_{\max} - yw_{\min}}$$

Continue…

Now we can express those two formulas for computing (vx, vy) from (wx, wy) in terms of a **translate-scale-translate** transformation N.

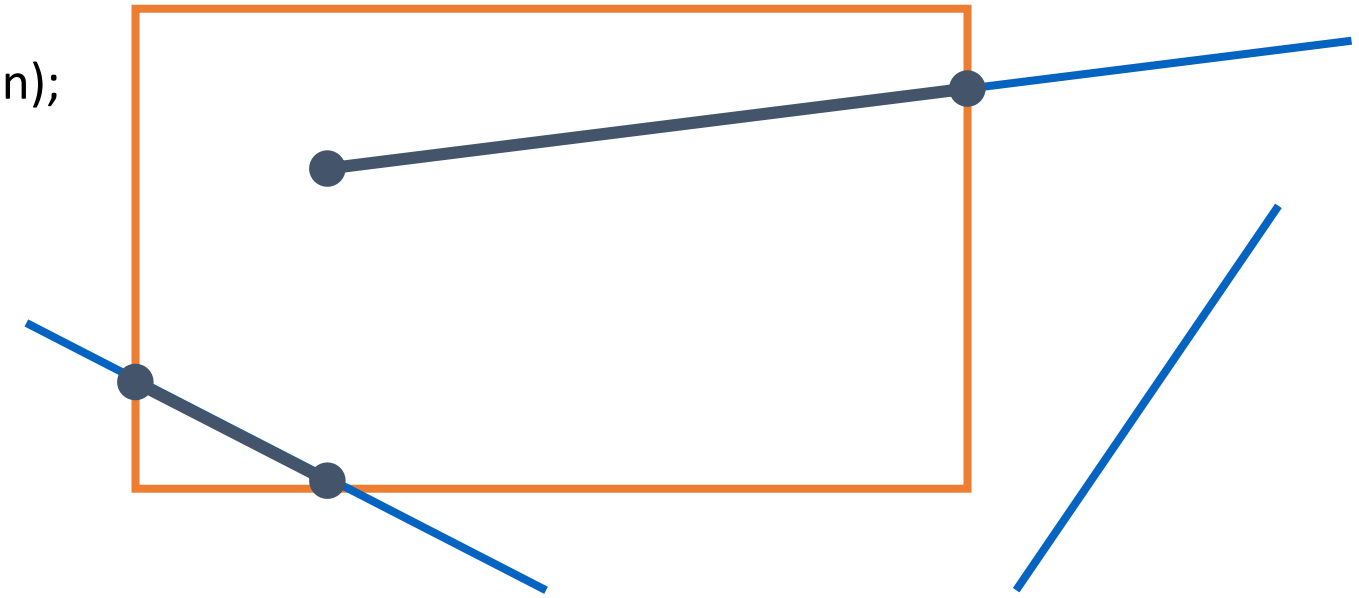
$$\begin{pmatrix} vx \\ vy \\ 1 \end{pmatrix} = N. \begin{pmatrix} wx \\ wy \\ 1 \end{pmatrix}$$

where

$$\mathrm{N} = \begin{bmatrix} 1 & 0 & xv_{\min} \\ 0 & 1 & yv_{\min} \\ 0 & 0 & 1 \end{bmatrix} . \begin{bmatrix} \dfrac{xv_{\max} - xv_{\min}}{xw_{\max} - xw_{\min}} & 0 & 0 \\ 0 & \dfrac{yv_{\max} - yv_{\min}}{yw_{\max} - yw_{\min}} & 0 \\ 0 & 0 & 1 \end{bmatrix} . \begin{bmatrix} 1 & 0 & -xw_{\min} \\ 0 & 1 & -yw_{\min} \\ 0 & 0 & 1 \end{bmatrix}$$

Clipping

- Analytically calculating the portions of primitives within the viewport.
- Adaptive primitive types:
  - Point;
  - Line;
  - Area (e.g. Polygon);



Point Clipping

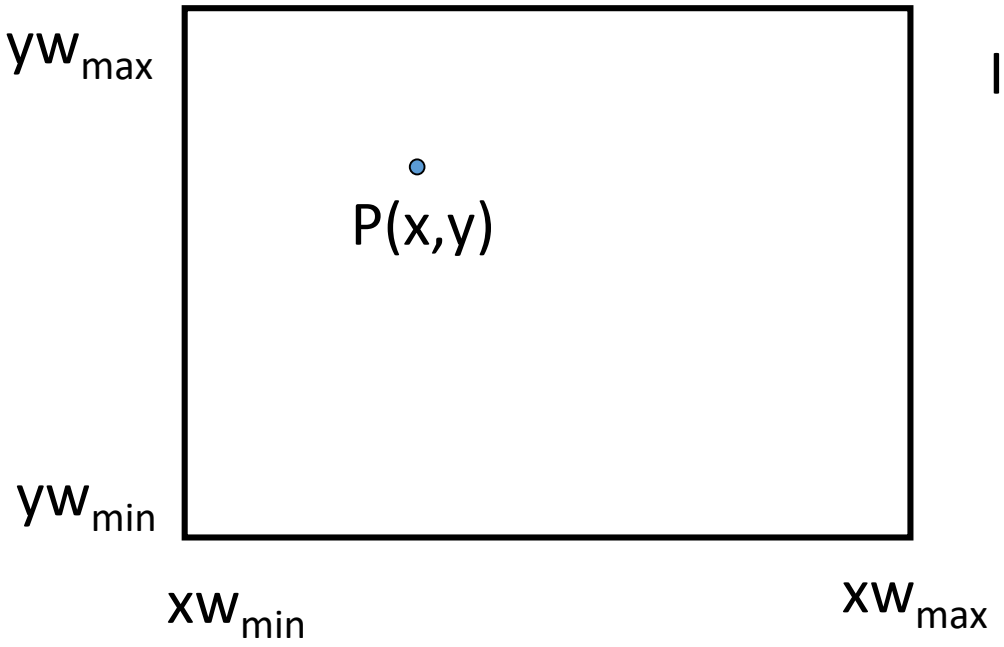
- Assuming that the clip window is a rectangle in standard position.
- For a clipping rectangle in standard position, we save a 2-D point P(x, y) for display if the following inequalities are satisfied:

$$x_{\min} \leq x \leq x_{\max}$$

$$y_{\min} \leq y \leq y_{\max}$$

- If any one of these four inequalities is not satisfied, the point is clipped (not saved for display).
- Where $x_{\min}, x_{\max}, y_{\min}, y_{\max}$ define the clipping window.

Point Clipping



If P(x,y) is inside the window?

$$xw_{\min} \leq x \leq xw_{\max}$$

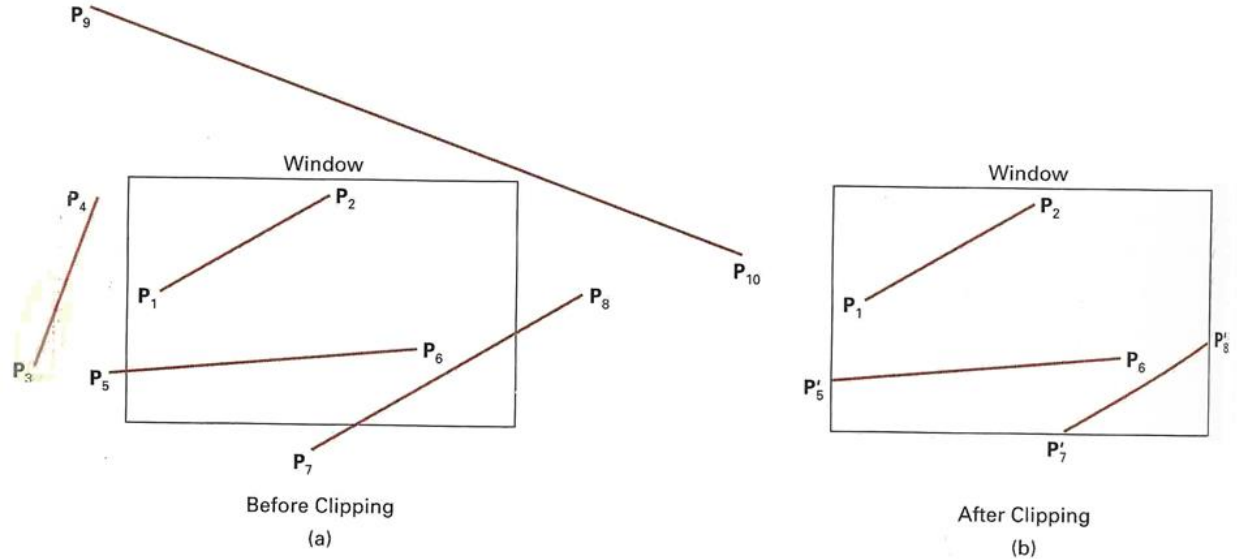
$$yw_{\min} \leq y \leq yw_{\max}$$

Line clipping

- **Line clipping procedure**
  - test a given line segment to determine whether it lies completely inside the clipping window.
  - if it doesn’t, we try to determine whether it lies completely outside the window.
  - if we can’t identify a line as completely inside or completely outside, we must perform intersection calculations with one or more clipping boundaries.

Line clipping

- Checking the line endpoints ⇒ inside-outside test.



- Line clipping Algorithm:
  - Cohen-Sutherland line clipping Algorithm;
  - Liang-Barsky line clipping Algorithm.

Thank you☺