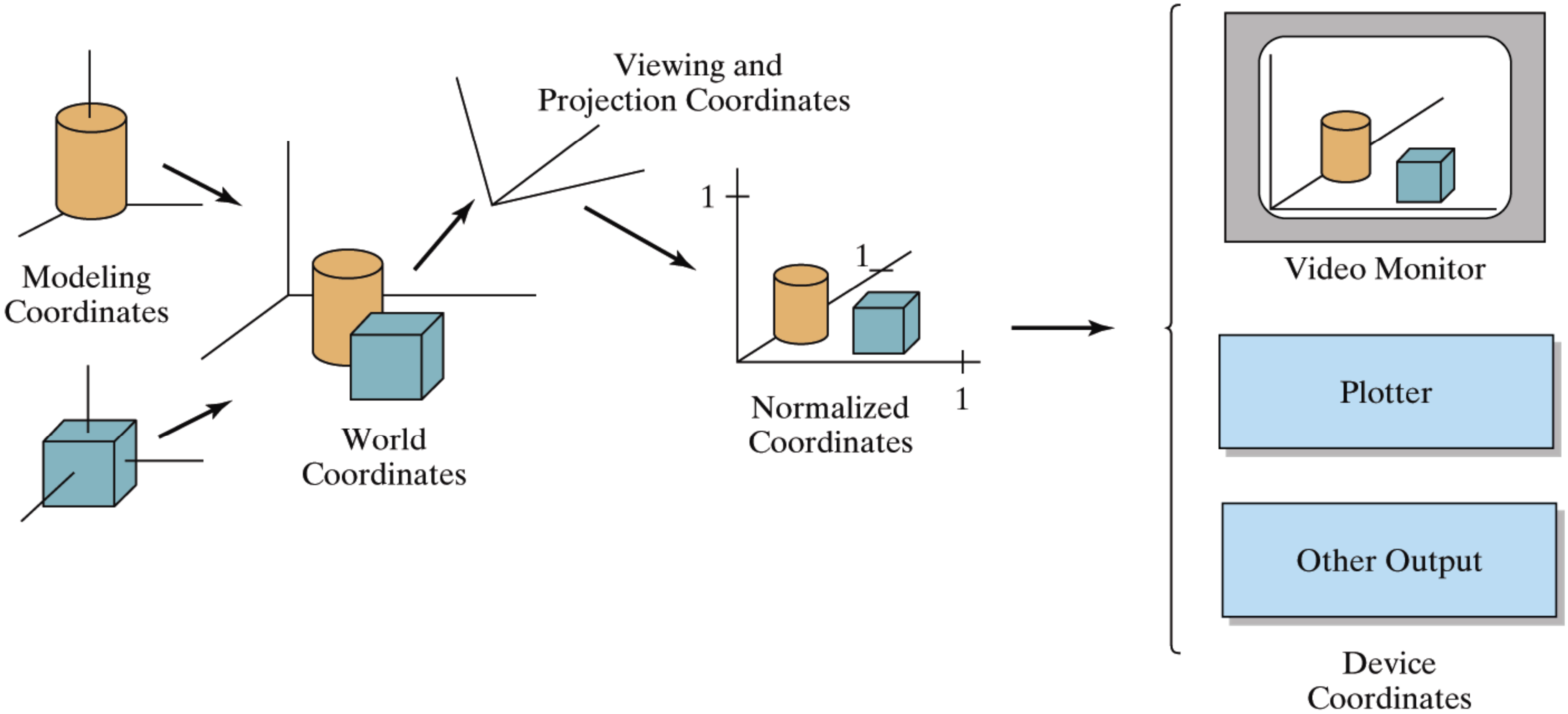
Two-Dimensional Viewing

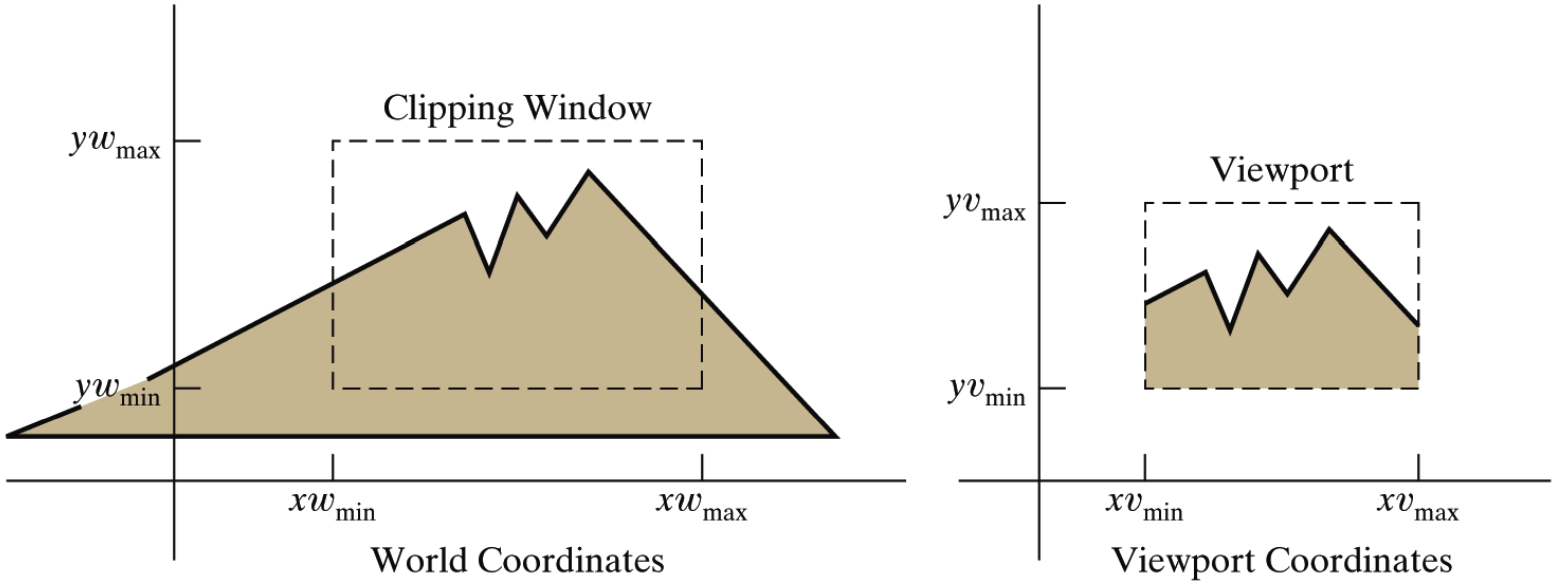
Chapter 6
Intro. to Computer Graphics
Spring 2008, Y. G. Shin

Viewing Pipeline



Two-Dimensional Viewing

- Two dimensional viewing transformation
  - From world coordinate scene description to device (screen) coordinates



Normalization and Viewport Transformation

- World coordinate clipping window
- Normalization square: usually [-1,1]x[-1,1]
- Device coordinate viewport

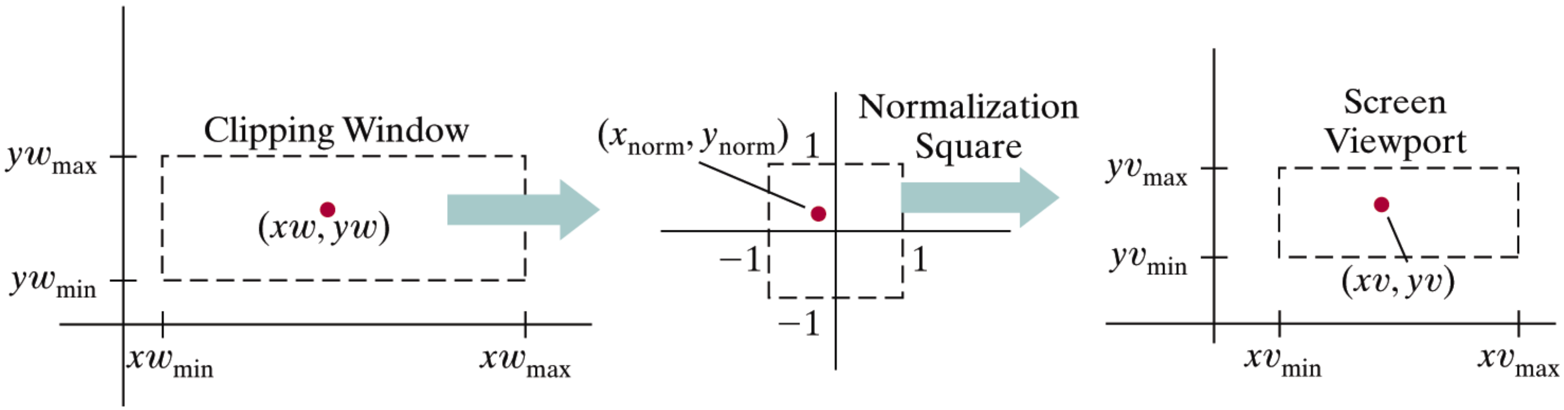


Figure 6-8

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.

Clipping

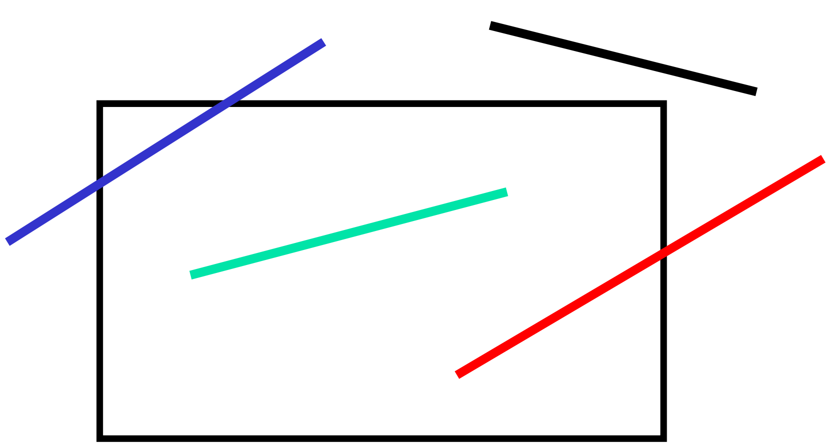
- Remove portion of line outside viewport or screen boundaries
- Two approaches:
  - Clip during scan conversion: per-pixel bounds check, or span endpoint tests.
  - Clip analytically, then scan-convert the modified primitive.

Two-Dimensional Clipping

- Point clipping – trivial
- Line clipping
  - Cohen-Sutherland
  - Cyrus-beck
  - Liang-Barsky
- Fill-area clipping
  - Sutherland-Hodgeman
  - Weiler-Atherton
- Curve clipping
- Text clipping

Line Clipping

- Basic calculations:
  - Is an endpoint inside or outside the clip rectangle?
  - Find the point of intersection, if any, between a line segment and an edge of the clip rectangle.

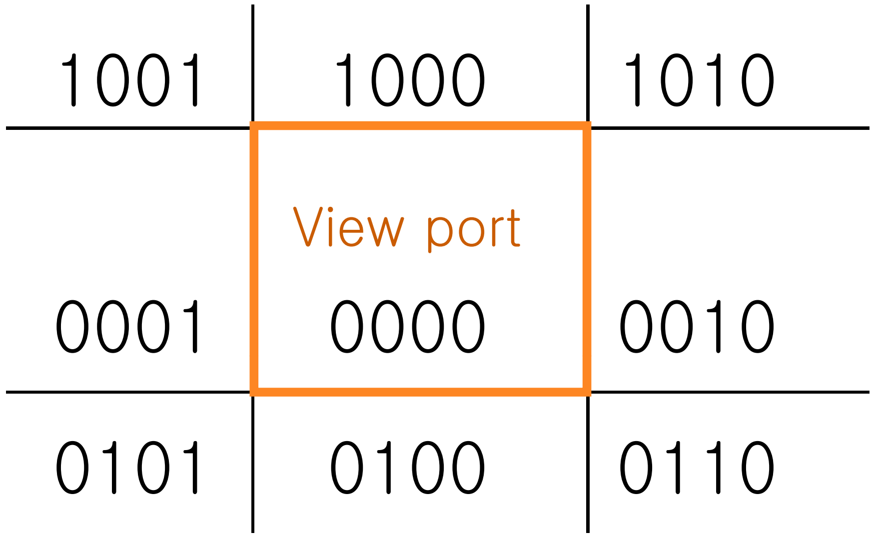


✓**Both endpoints inside: trivial accept**

✓**One inside: find intersection and clip**

✓**Both outside: either clip or reject**

Cohen-Sutherland Line-Clipping Algorithm



< Region code for each endpoint >

above	below	right	left
Bit 4	3	2	1

Cohen-Sutherland Line-Clipping Algorithm

- Trivially accepted

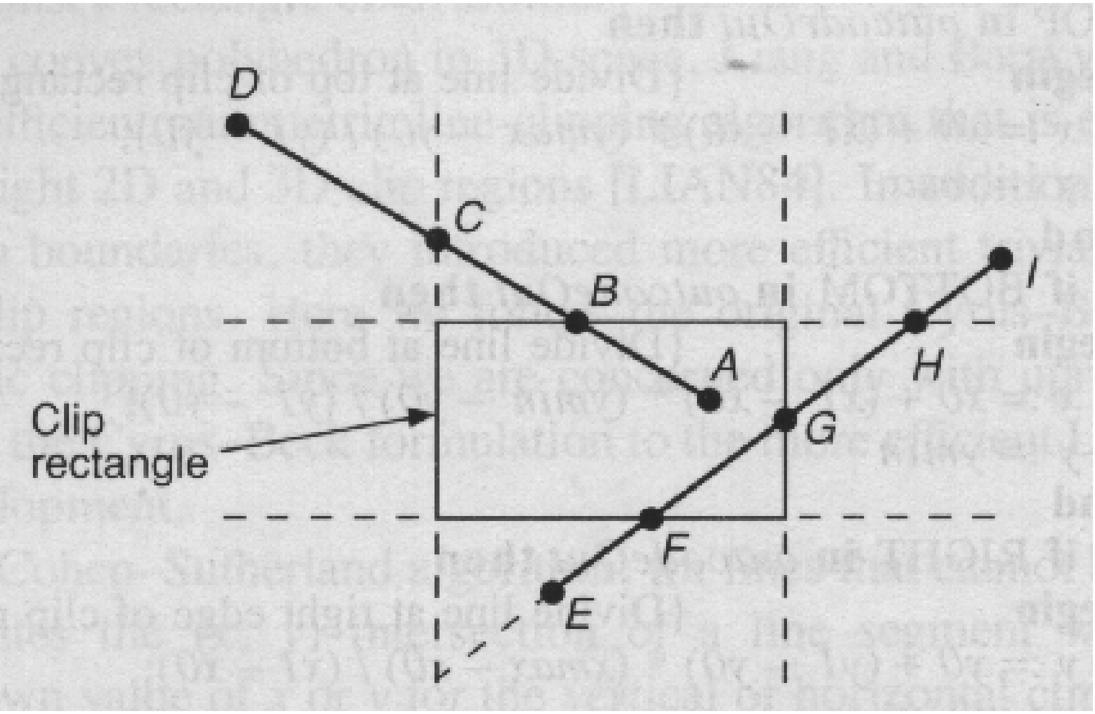
  if (both region codes = 0000)
- Trivially rejected

  if (AND of region codes ≠ 0000)
- Otherwise, divide line into two segments
  - test intersection edges in a fixed order.

    (e.g., top-to-bottom, right-to-left)

Cohen-Sutherland Line-Clipping Algorithm

* fixed order testing and clipping cause needless clipping (external intersection)



Cohen-Sutherland Line-Clipping Algorithm

- Midpoint Subdivision for locating intersections

  1. trivial accept/reject test
  2. midpoint subdivision:

     $x_m = (x_1 + x_2)/2$, $y_m = (y_1 + y_2)/2$

     (one addition and one shift)
  3. repeat step 1 with two halves of line

  $\Rightarrow$ good for hardware implementation

Cohen-Sutherland Line-Clipping Algorithm

- When this is good
  - If it can trivially reject most cases
  - Works well if a window is large w.r.t. to data
  - Works well if a window is small w.r.t. to data
  - i.e., it works well in extreme cases
  - Good for hardware implementation

Parametric Line Clipping (Cyrus-beck Technique)

- Use a parametric line equation

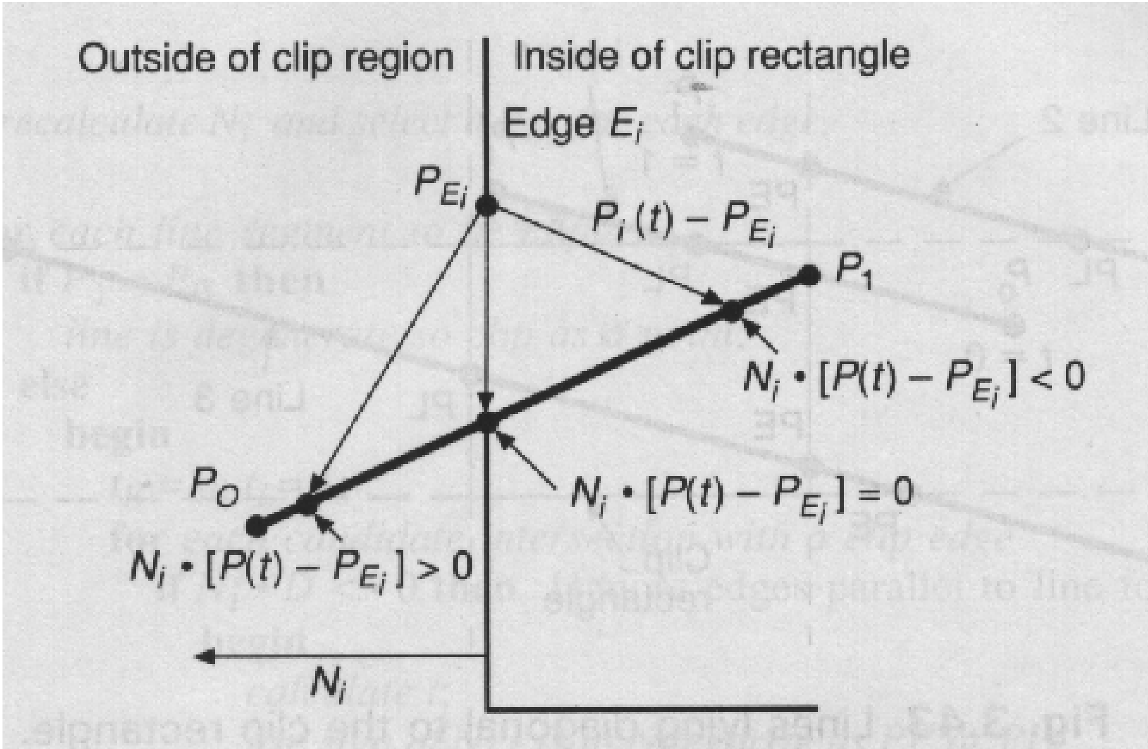
$$P(t) = P_0 + t(P_1 - P_0), \quad 0 \le t \le 1$$

- Reduce the number of calculating intersections by simple comparisons of parameter *t*.

Parametric Line Clipping (Cyrus-beck Technique)

Algorithm

- For each edge E_i of the clip region
- N_i : outward normal of E_i



Parametric Line Clipping (Cyrus-beck Technique)

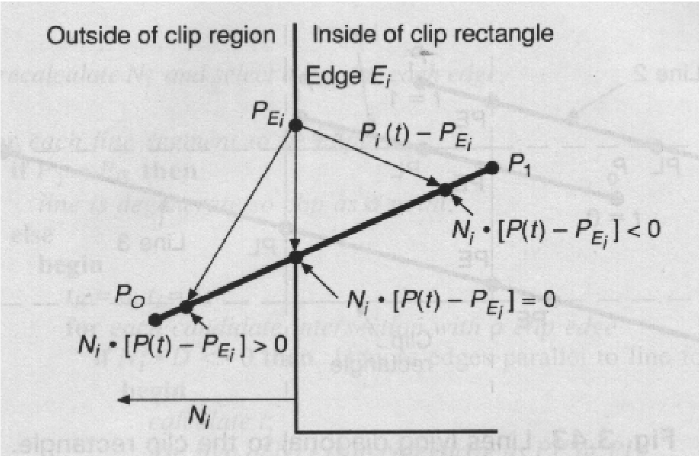
- Choose an arbitrary point P_{E_i} on edge E_i and consider three vectors $P(t) - P_{E_i}$

$\Rightarrow$

$$N_i \bullet (P(t) - P_{E_i}) < 0 \Leftrightarrow \text{a point in the side halfplane}$$

$$N_i \bullet (P(t) - P_{E_i}) = 0 \Leftrightarrow \text{a point on the line containing the edge}$$

$$N_i \bullet (P(t) - P_{E_i}) > 0 \Leftrightarrow \text{a point in the outside halfplane}$$



Parametric Line Clipping (Cyrus-beck Technique)

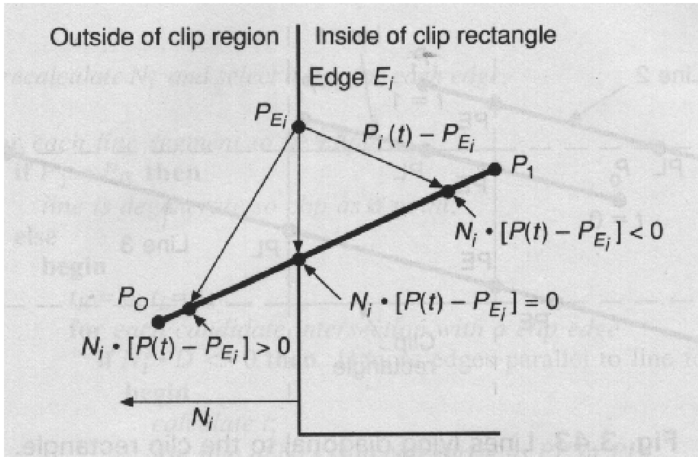
- Solve for the value of *t* at the intersection of P_0P_1 with the edge:

  $N_i \cdot [P(t) - P_{Ei}] = 0.$

  $P(t) = P_0 + t(P_1 - P_0)$ and let $D = (P_1 - P_0)$,

  Then

$$t = \frac{N_i \cdot [P_0 - P_{Ei}]}{-N_i \cdot D}$$



  $N_i \neq 0$,

  $D \neq 0$ (that is $P_0 \neq P_1$),

  $N_i \cdot D \neq 0$ (if not, no intersection)

Parametric Line Clipping (Cyrus-beck Technique)

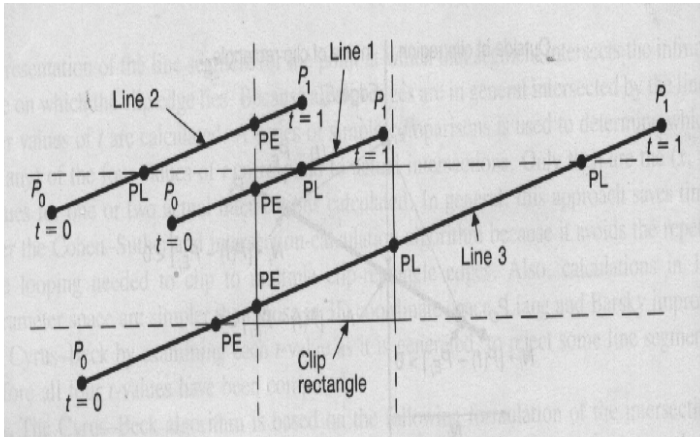
- Given the four values of t for a line segment, determine which pair of *t*'s are internal intersections.

  If $t \notin [0,1]$ then discard

  else choose a (PE, PL) pair

  that defines the

  clipped line.



- PE(potentially entering) intersection:

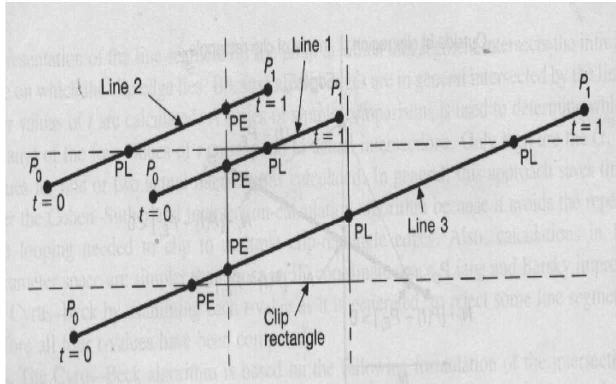
  if moving from P_0 to P_1 causes us to cross an edge to enter the edge's inside half plane;

Parametric Line Clipping (Cyrus-beck Technique)

- PL(potentially leaving) intersection:
  - if moving from P_0 to P_1 causes us to leave the edge's inside half plane.

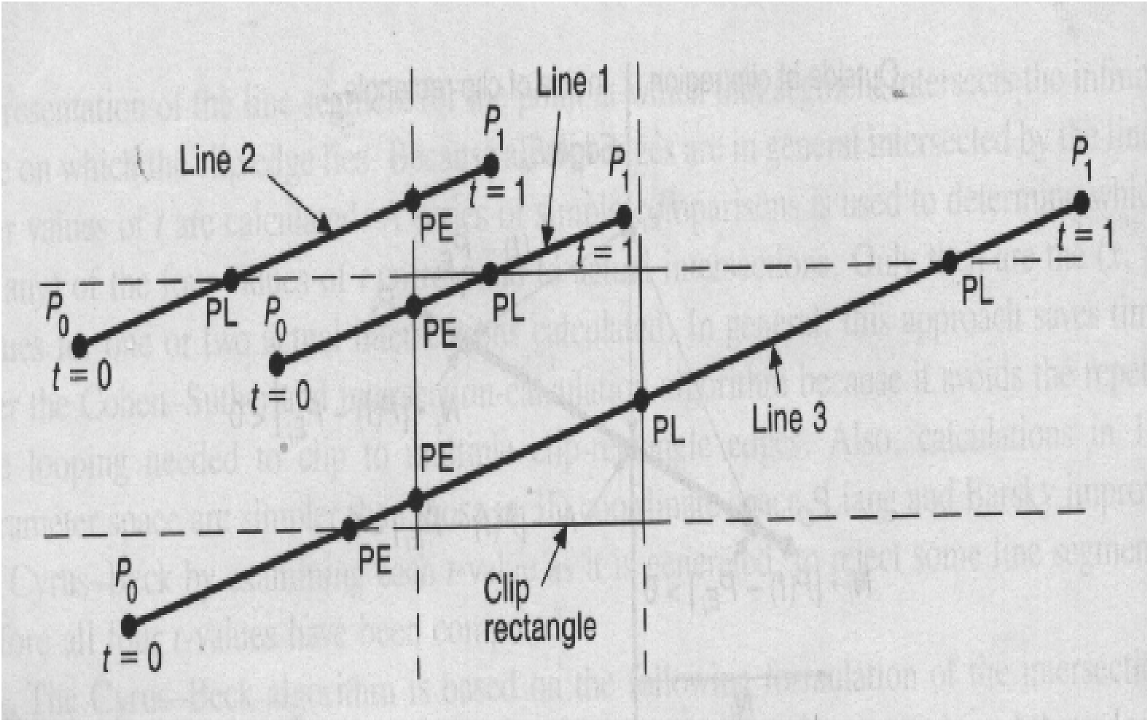
$$\text{i.e.,}\quad N_i \bullet P_0P_1 < 0 \Rightarrow \text{PE}$$

$$N_i \bullet P_0P_1 > 0 \Rightarrow \text{PL}$$



- Intersections can be categorized!
- Inside the clip rectangle (T_E, T_L)
  - T_E: select PE with largest t value ≥ 0
  - T_L: select PL with the smallest t value ≤ 1.

Parametric Line Clipping (Cyrus-beck Technique)

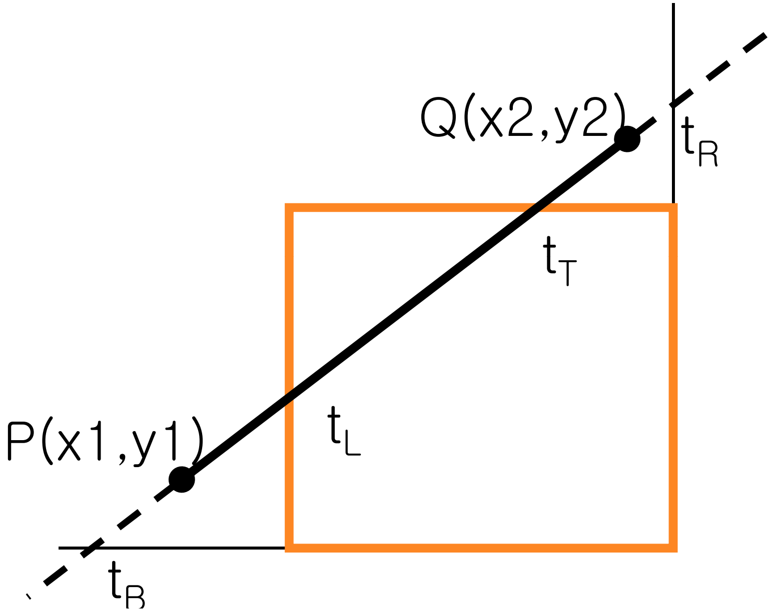


- This is an efficient algorithm when many line segments need to be clipped
- Can be extended easily to convex polygon windows

Liang-Barsky line clipping

- The ideas for clipping line of Liang-Barsky and Cyrus-Beck are the same. The only difference is Liang-Barsky algorithm has been optimized for an upright rectangular clip window.
- Finds the appropriate end points with more efficient computations.

Liang-Barsky line clipping



Let PQ be the line which we want to study

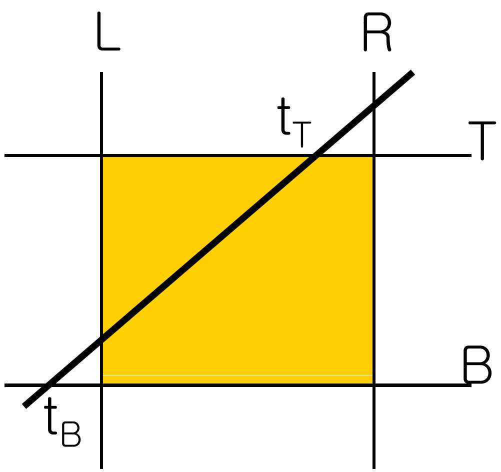
Parametric equation of the line segment

$$x = x1 + (x2 - x1)t = x1 + dx \times t$$
$$y = y1 + (y2 - y1)t = y1 + dy \times t$$

$$t = 0 \Rightarrow P(x1, y1)$$
$$t = 1 \Rightarrow Q(x2, y2)$$

Liang-Barsky Line Clipping

1. Set $t_{min} = 0$ and $t_{max} = 1$
2. Calculate the values of t_T, t_B, t_L, t_R,



Top edge: y = T

$$y_1 + t^*(y_2 - y_1) = T$$

$$t_T = \frac{T - y_1}{y_2 - y_1}$$

Bottom edge: y = B

$$y_1 + t^*(y_2 - y_1) = B$$

$$t_B = \frac{B - y_1}{y_2 - y_1}$$

Left edge: x = L

$$x_1 + t^*(x_2 - x_1) = L$$

$$t_L = \frac{L - x_1}{x_2 - x_1}$$

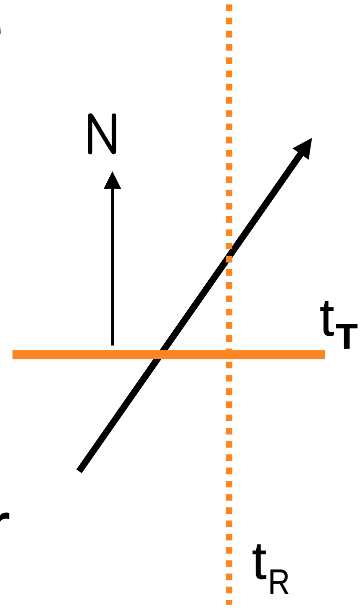
Right edge: x = R

$$x_1 + t^*(x_2 - x_1) = R$$

$$t_R = \frac{R - x_1}{x_2 - x_1}$$

Liang-Barsky Line Clipping

- If $t < t_{min}$ or $t > t_{max}$, ignore it and go to the next edge.
- Otherwise classify the t value as entering or exiting value (using the inner product to classify)
  - Let PQ be the line and N is normal vector
  - If $N \bullet (Q - P) \leq 0$, the parameter t is entering
  - If $N \bullet (Q - P) > 0$, the parameter t is exiting
- If t is entering value, set $t_{min} = t$, if t is exiting value set $t_{max} = t$

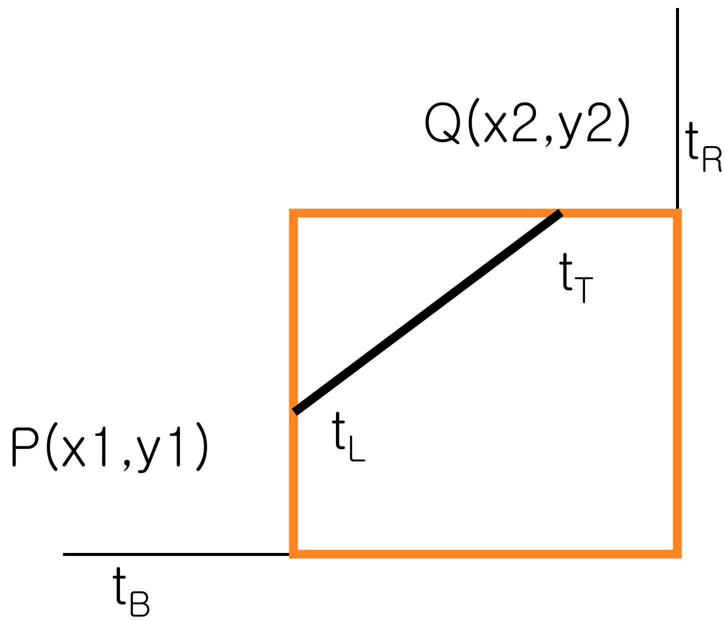


Liang-Barsky Line Clipping

3. If $t_{min} < t_{max}$ then draw a line

$$\text{from } (x1 + dx \times t_{min}, y1 + dy \times t_{min})$$

$$\text{to } (x1 + dx \times t_{max}, y1 + dy \times t_{max})$$

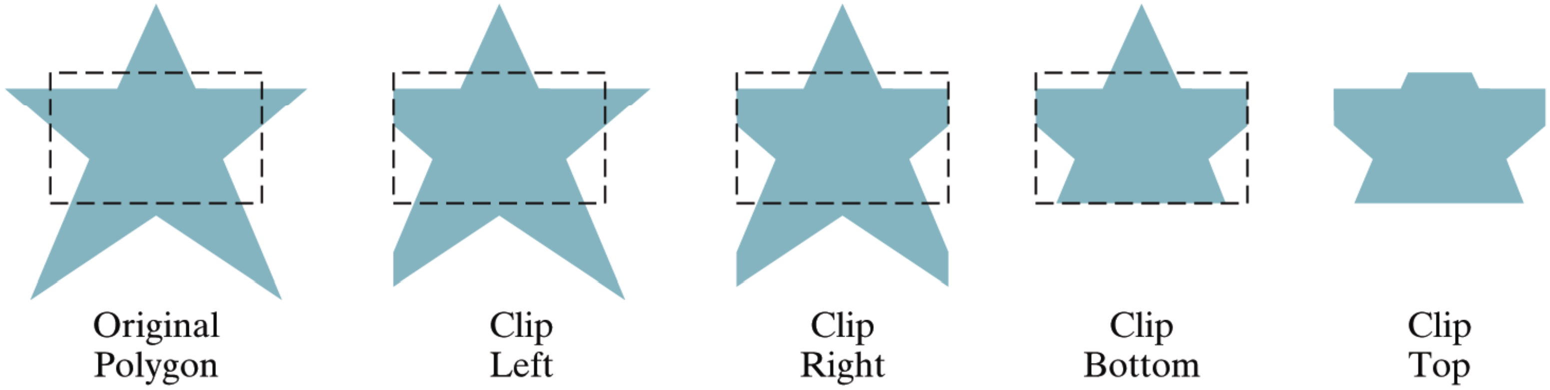


Clipping

- Clipping rotated windows, circles
  - trivial acceptance/rejection test with respect to bounding rectangle of the window
- Line clipping using nonrectangular clip windows
  - extend Cyrus-Beck algorithm

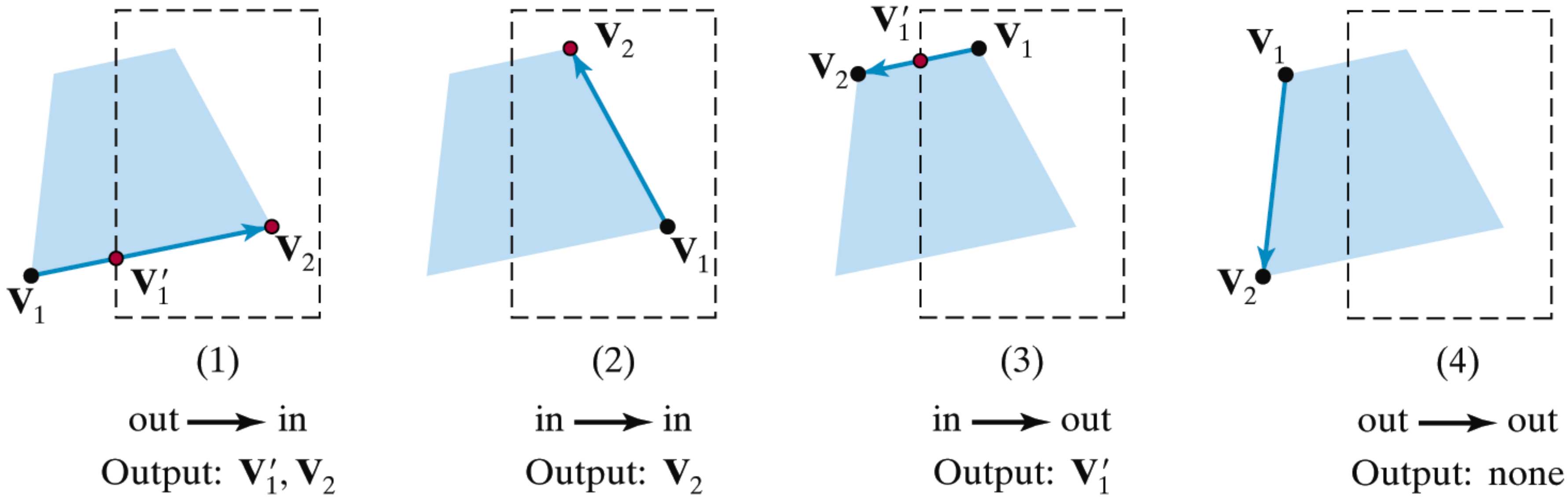
Polygon clipping

- Sutherland-Hodgeman Algorithm
  - clip against 4 infinite clip edge in succession



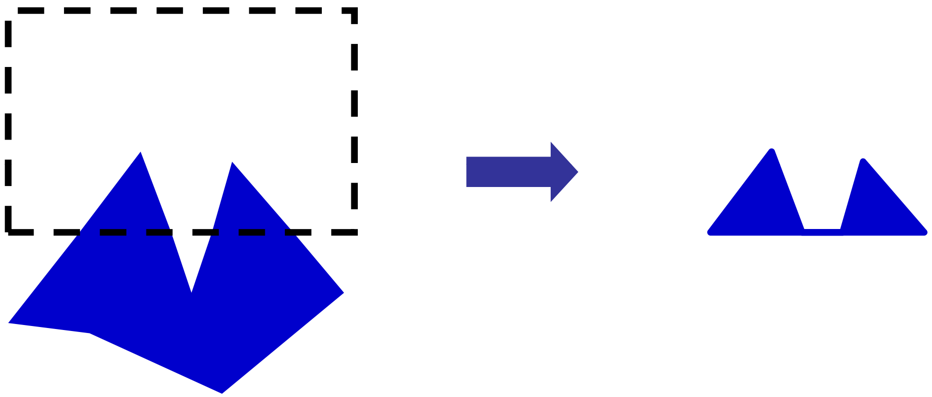
Sutherland-Hodgeman Algorithm

- Accept a series of vertices (polygon) and outputs another series of vertices
- Four possible outputs



Sutherland-Hodgeman Algorithm

- The algorithm correctly clips convex polygons, but may display extraneous lines for concave polygons.



- How clip?

How to correctly clip

[Way I] Split the concave polygon into two or more convex polygons and process each convex polygon separately.

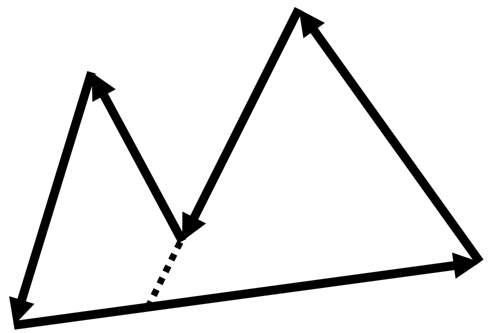
[Way II] Modify the algorithm to check the final vertex list for multiple vertex points along any clip window boundary and correctly join pairs of vertices.

[Way III] Use a more general polygon clipper

Clipping concave polygons

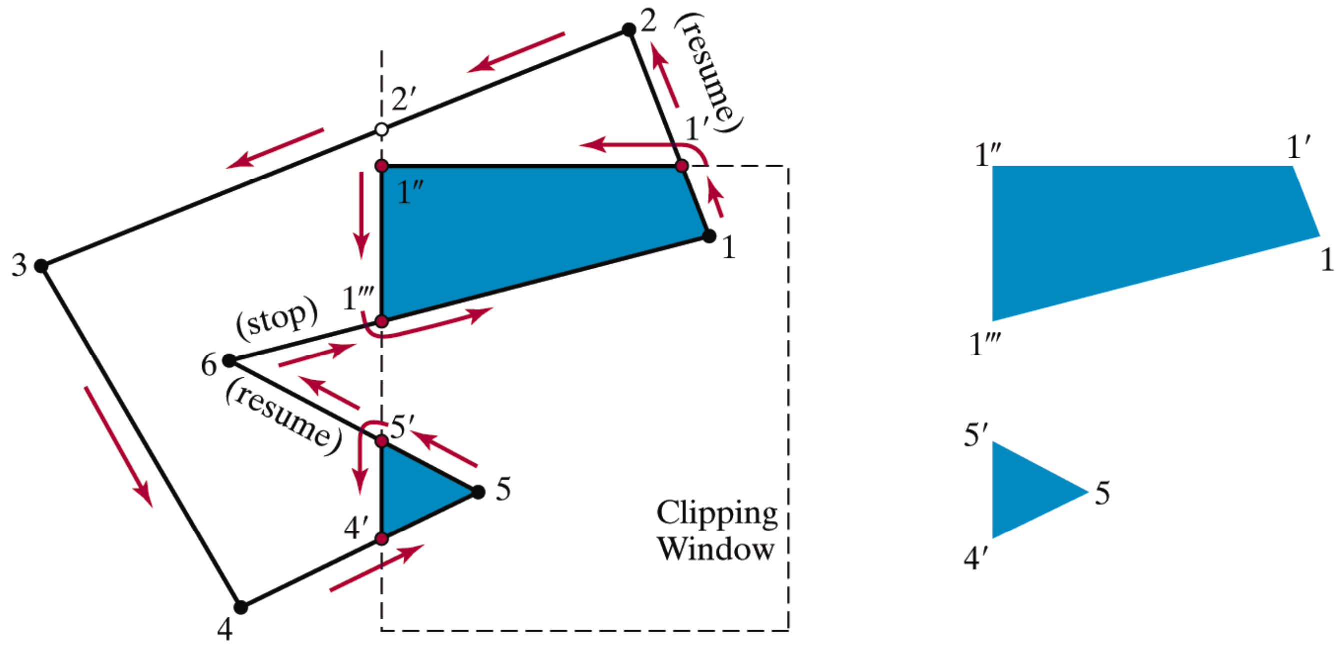
- Split the concave polygon into two or more convex polygons and process each convex polygon separately.
  - vector method for splitting concave polygons

    ⇒ calculate edge-vector cross products in a counterclockwise order. If any z component turns out to be negative, the polygon is concave.



Weiler-Atherton Polygon Clipping

- For an outside-to-inside pair of vertices, follow the polygon boundary.
- For an inside-to-outside pair of vertices, follow the window boundary in a clockwise direction.



Weiler-Atherton Polygon Clipping

- Polygon clipping using nonrectangular polygon clip windows

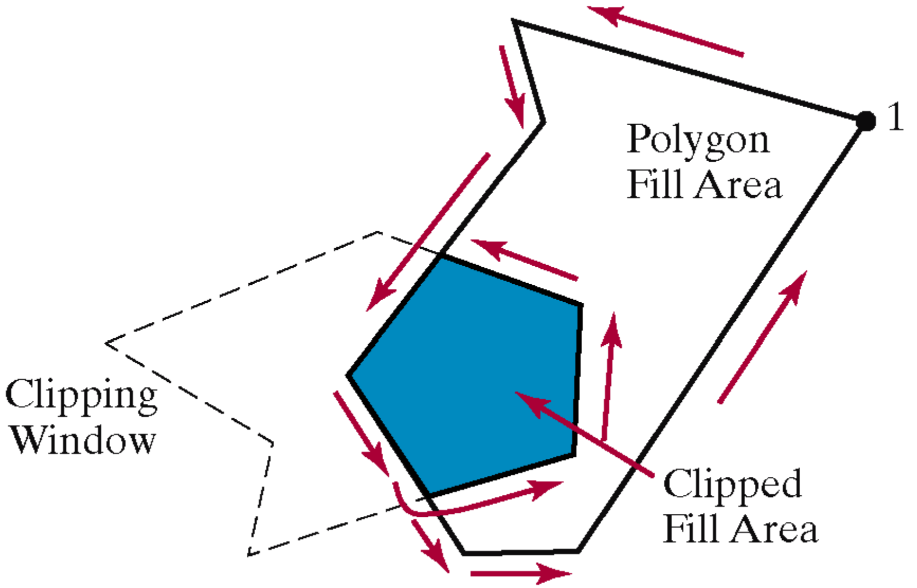
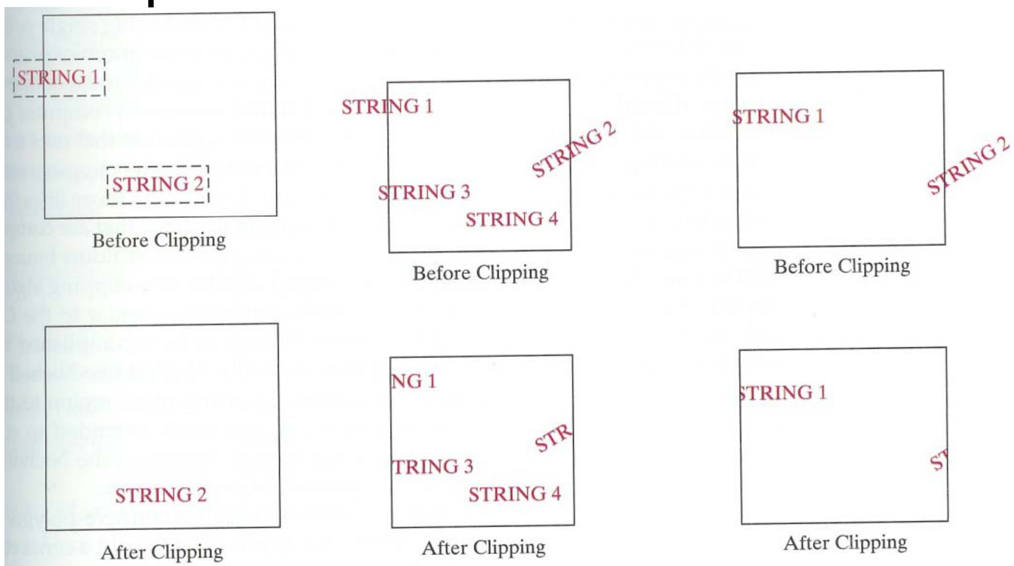


Figure 6-30

Clipping a polygon fill area against a concave-polygon clipping window using the Weiler-Atherton algorithm.

Texture Clipping

1. all-or-none text clipping : Using boundary box for the entire text
2. all-or-none character clipping : Using boundary box for each individual
3. clip individual characters
   - vector : clip line segments
   - bitmap : clip individual pixels



What we have got!