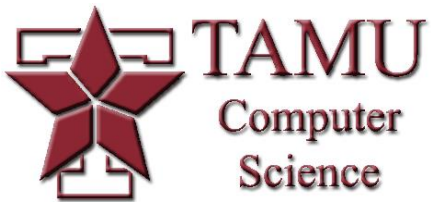
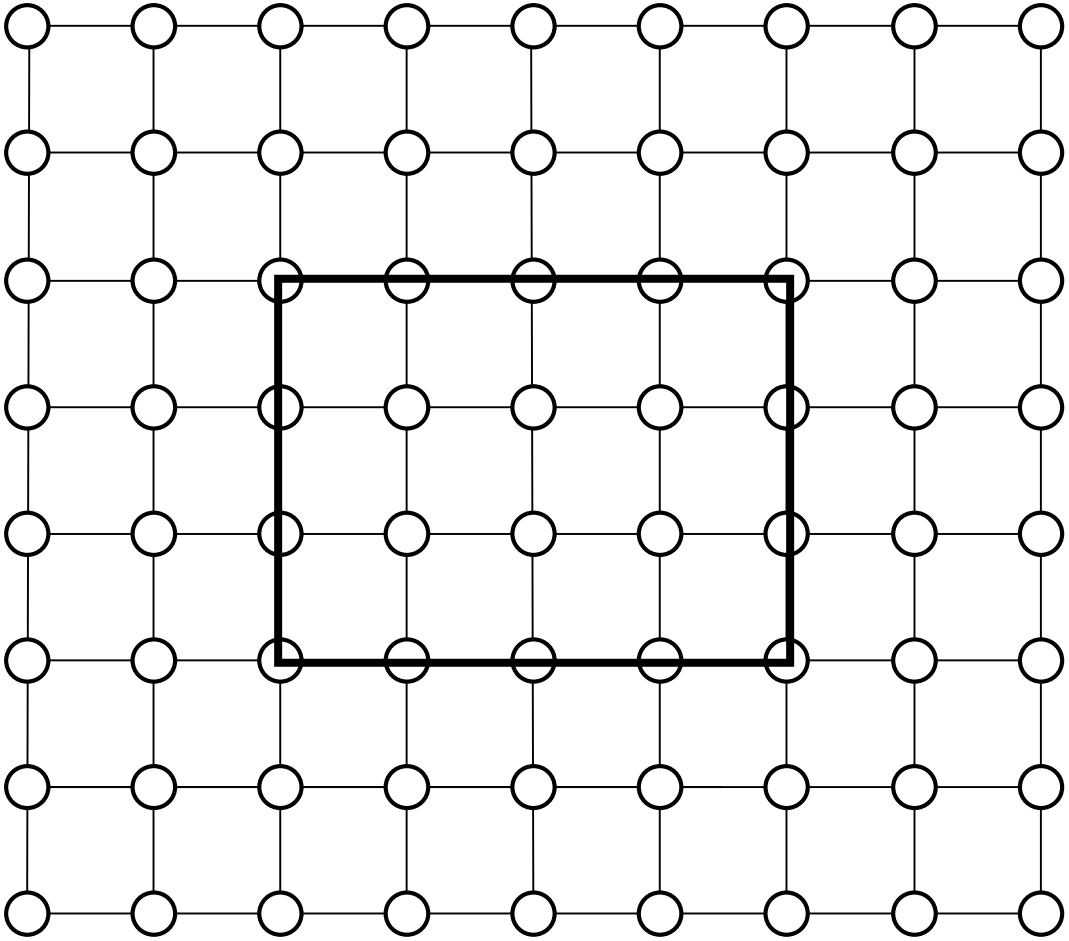
Scan Conversion of Polygons

Dr. Scott Schaefer



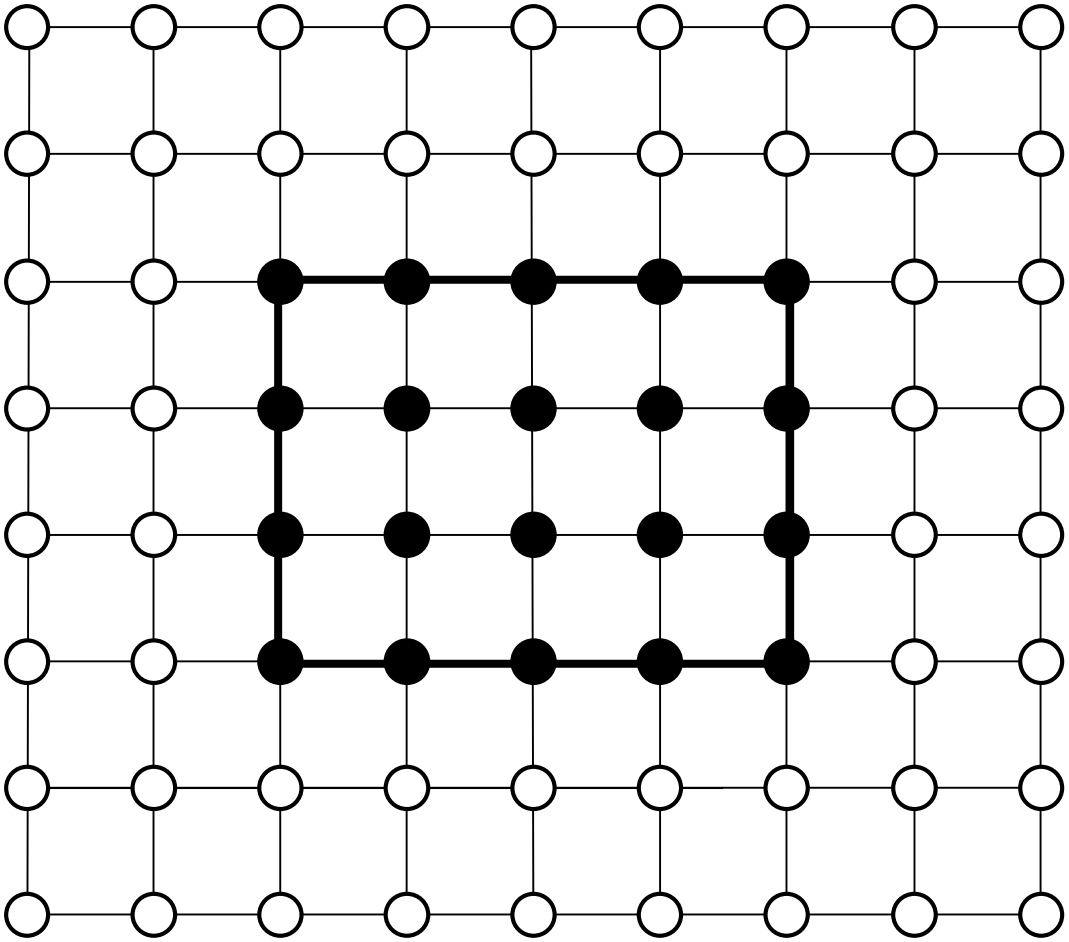
Drawing Rectangles

Which pixels should be filled?



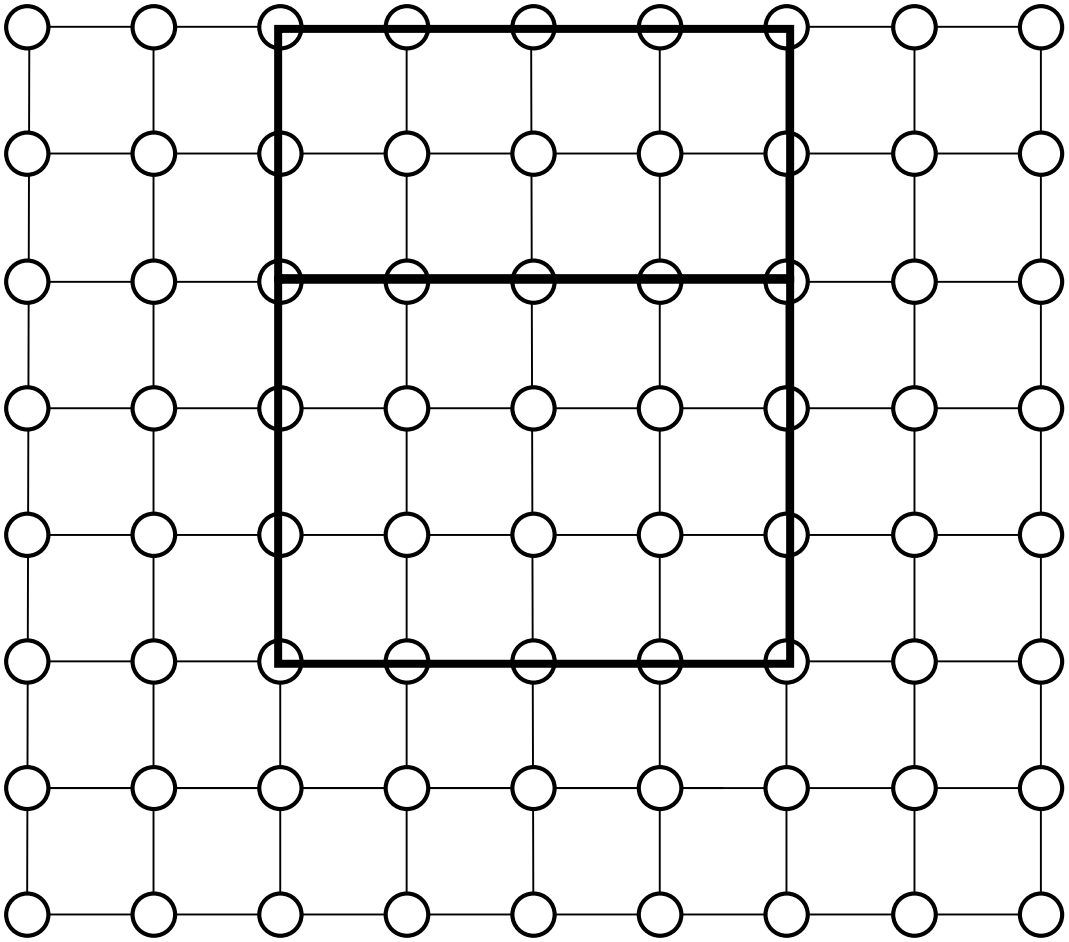
Drawing Rectangles

Is this correct?



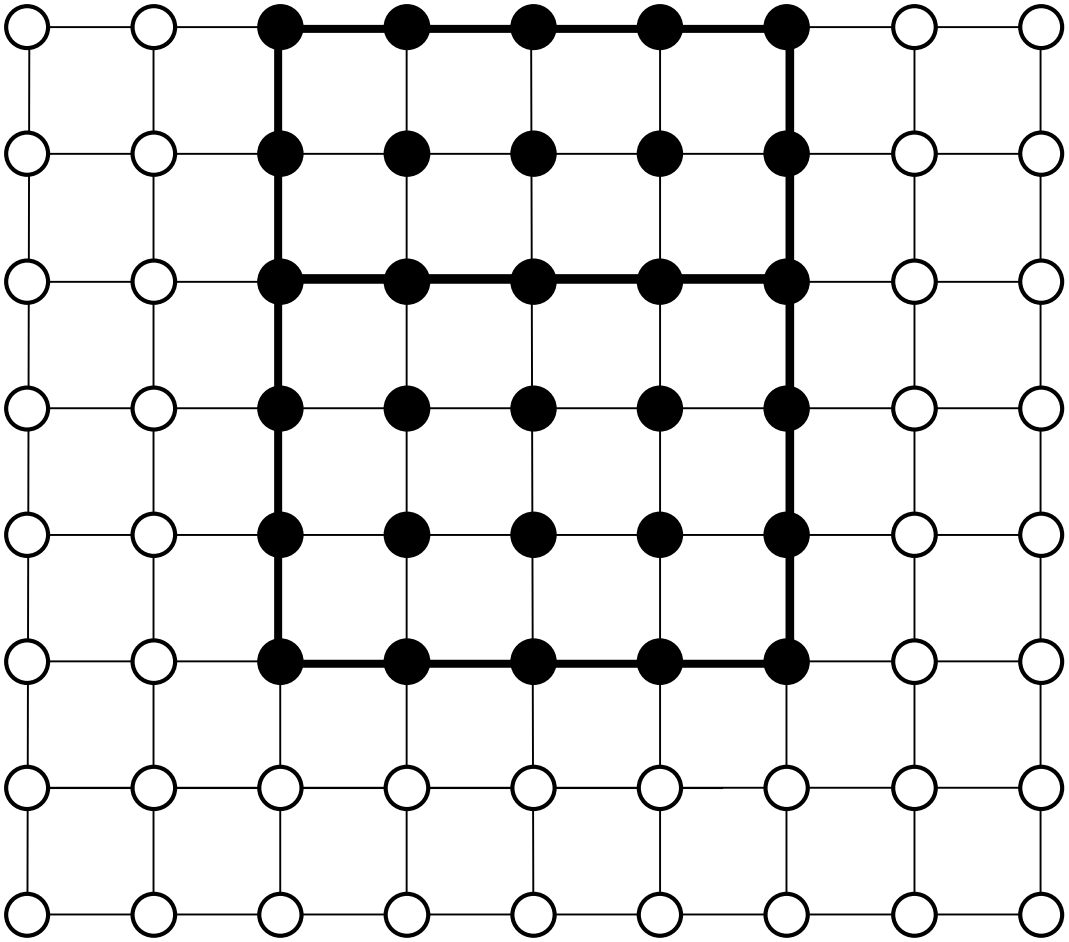
Drawing Rectangles

What if two rectangles overlap?

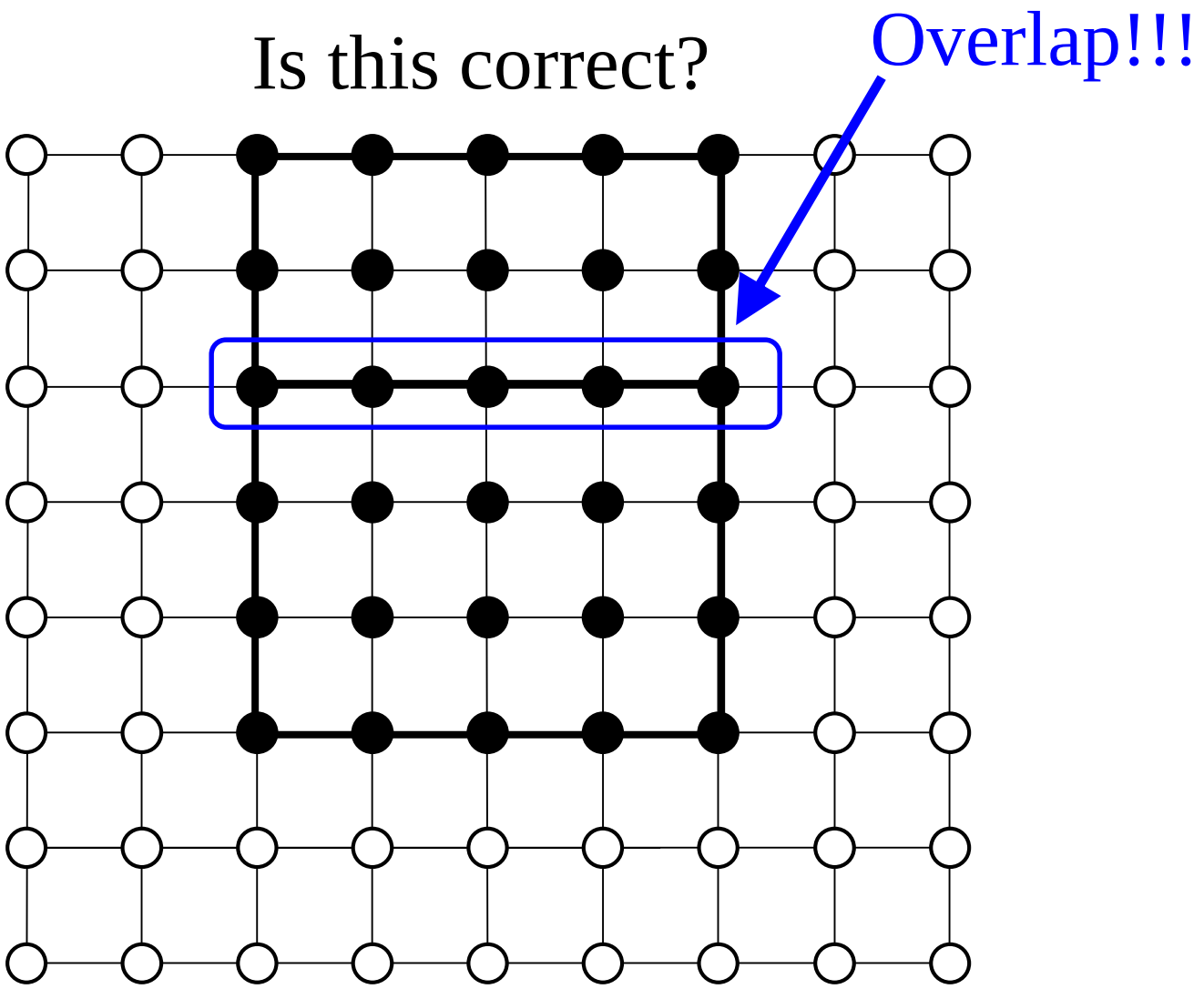


Drawing Rectangles

Is this correct?

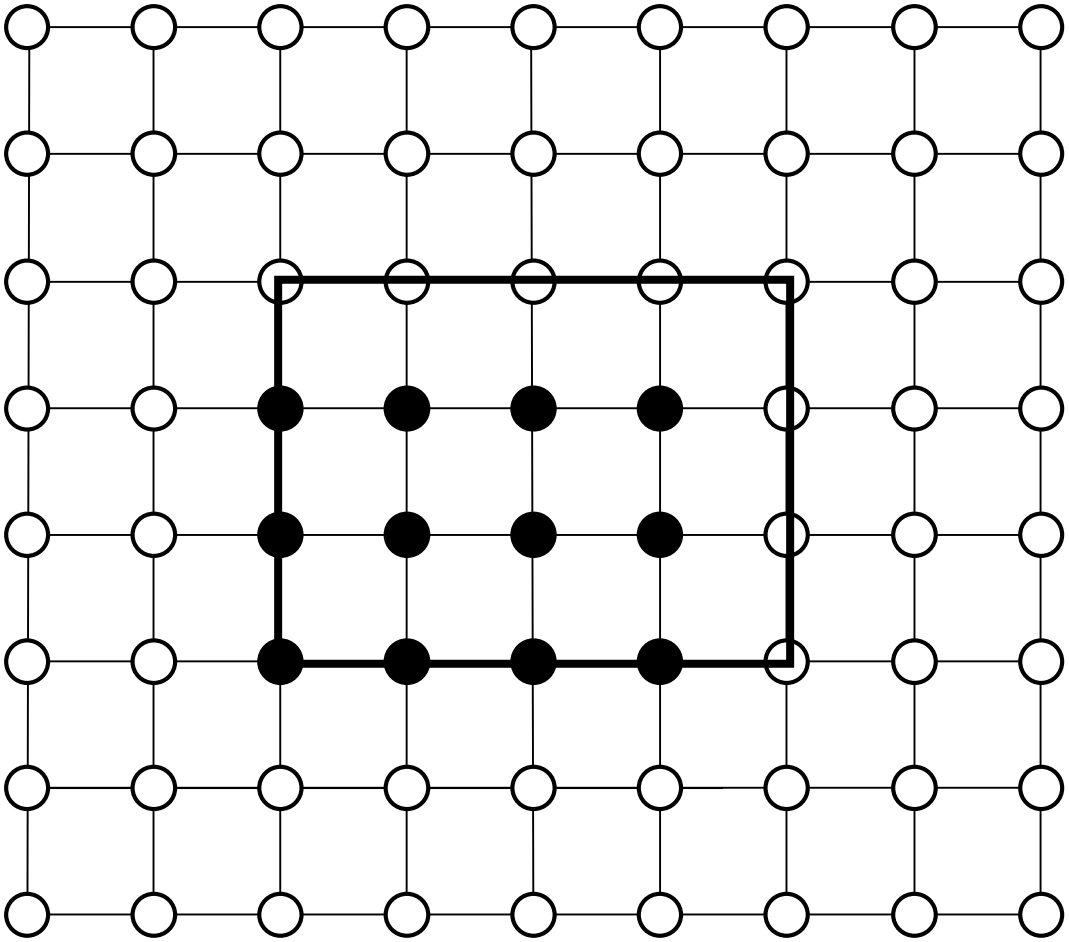


Drawing Rectangles



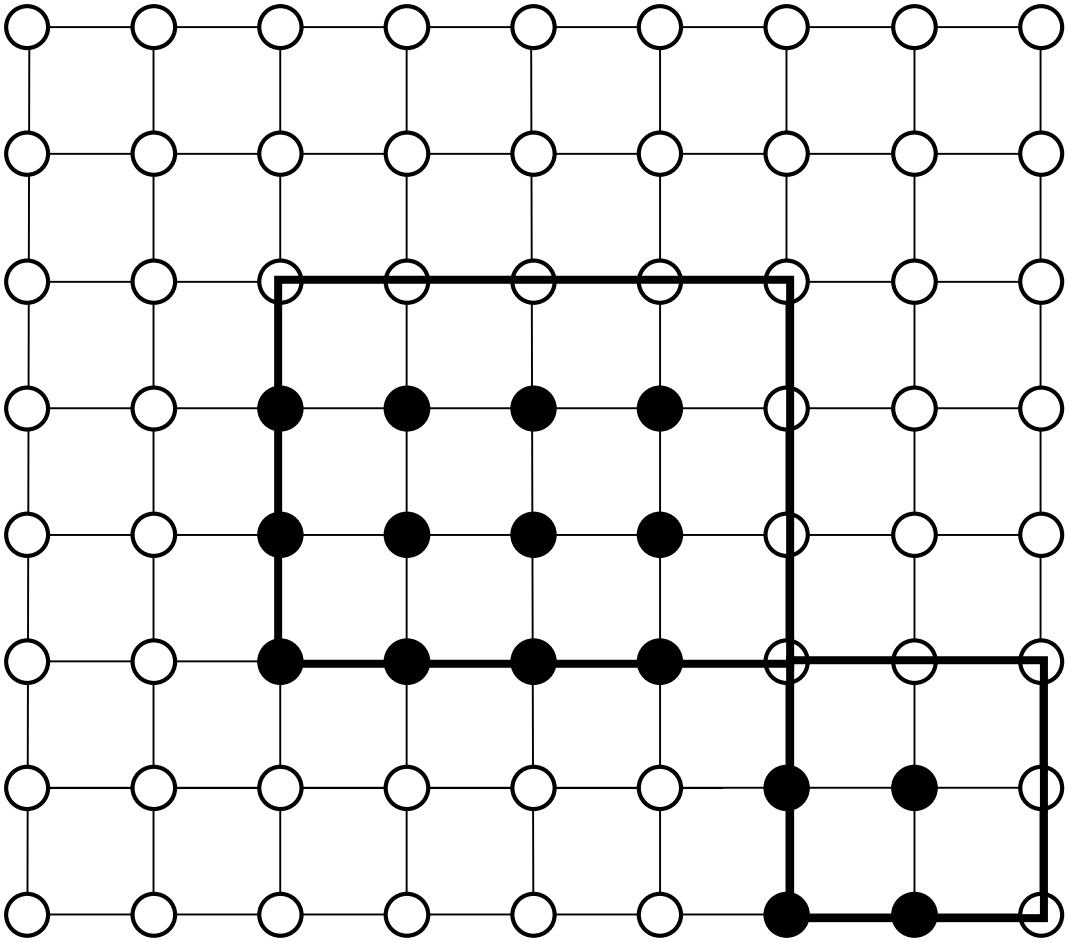
Drawing Rectangles

Solution: Exclude pixels on top and right



Drawing Rectangles

Artifacts are possible

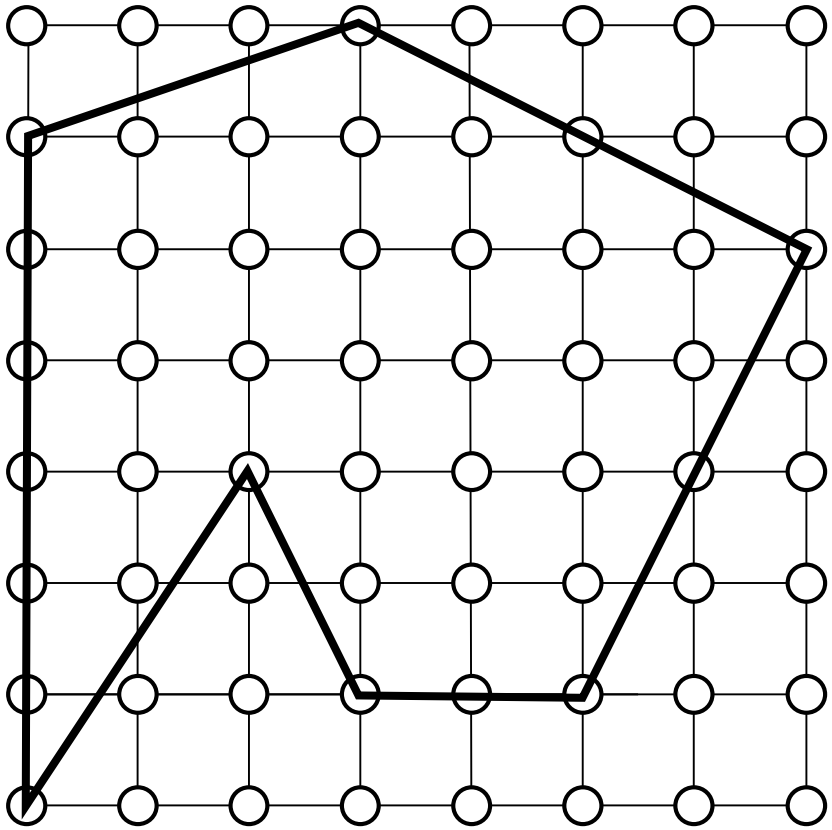


General Polygons – Basic Idea

- Intersect scan lines with edges
- Find ranges along *x*
- Fill interior of those ranges

Don’t fill top/right

Edges may NOT match with line drawing algo



General Polygons – Basic Idea

- Intersect scan lines with edges
- Find ranges along *x*
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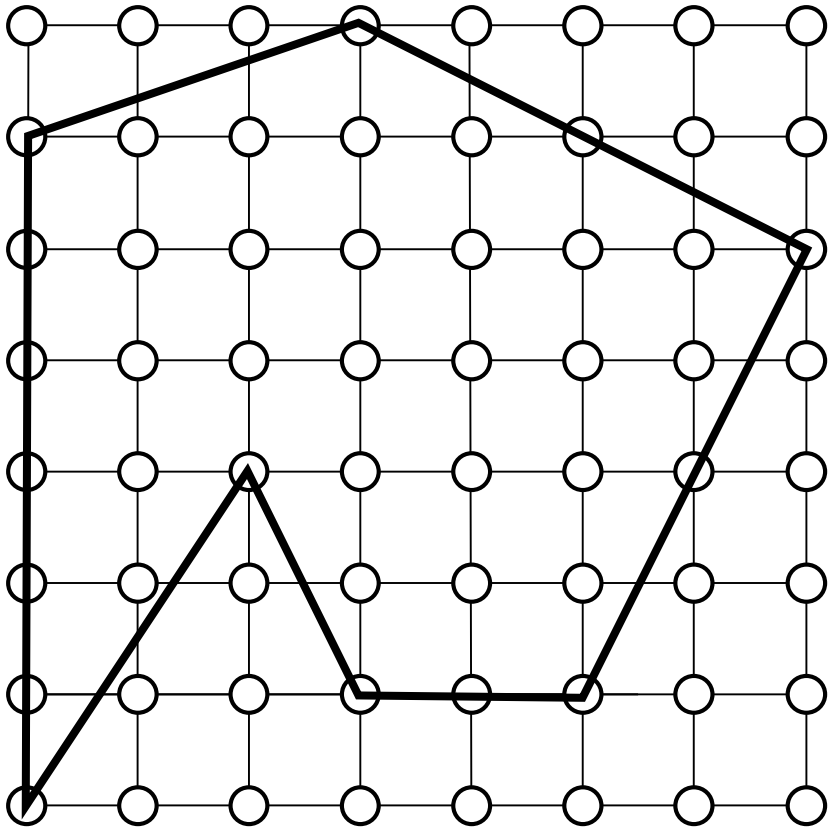
Use coherence to speed up



Don’t fill top/right

Edges may NOT match with line drawing algo

General Polygons – Basic Idea

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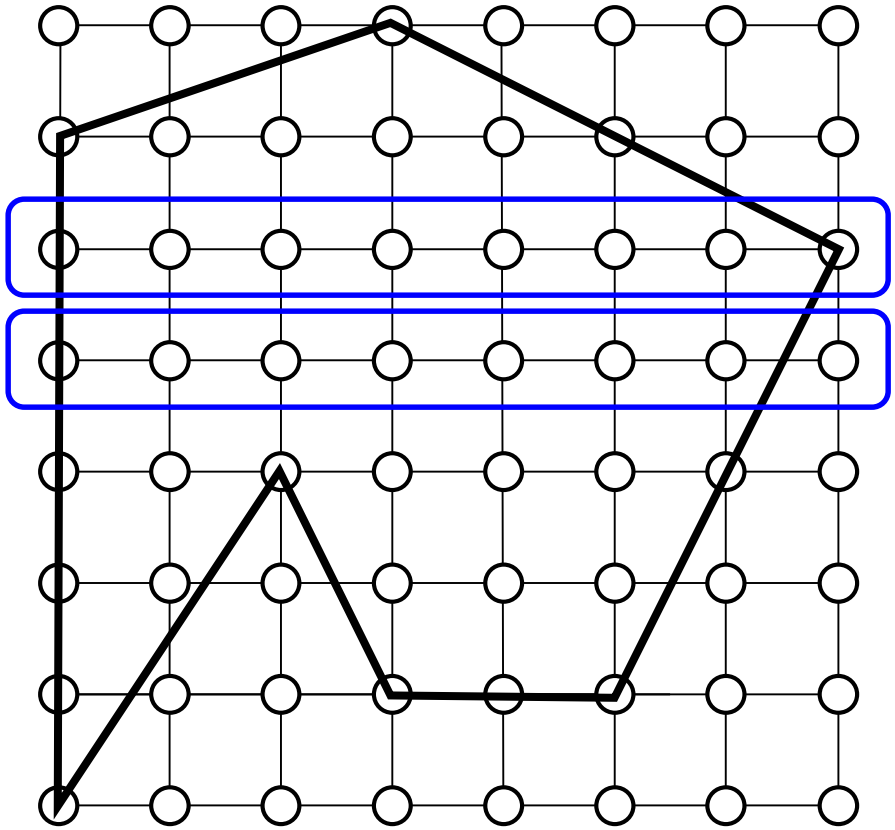
Use coherence to speed up

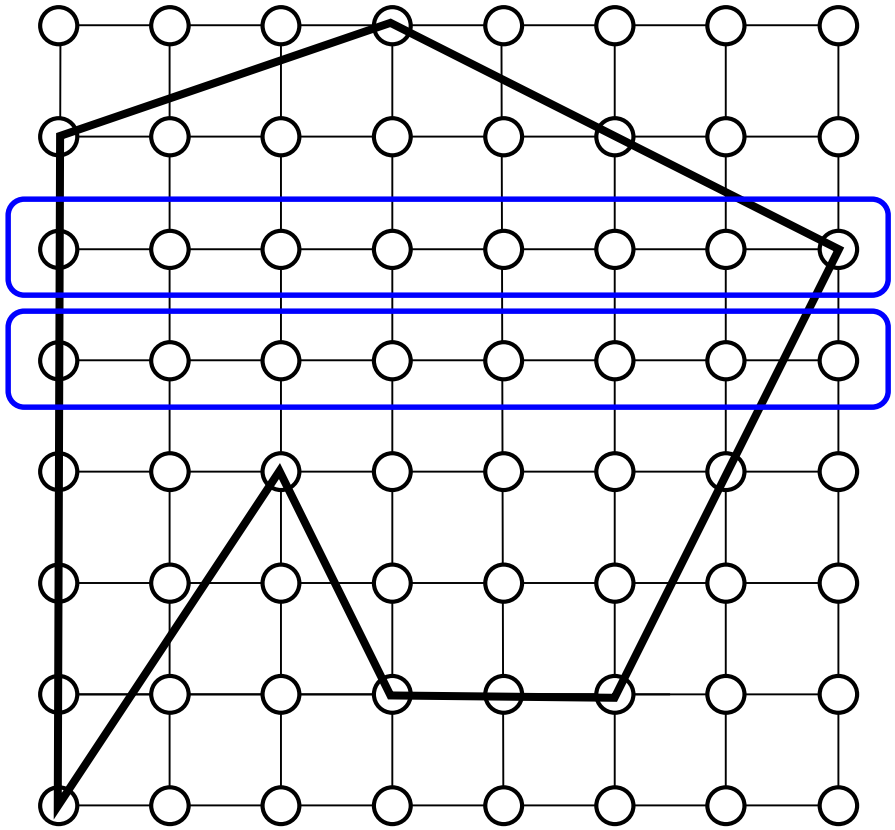


Edges intersection one scan line are mostly same as those intersecting previous scan line

General Polygons – Basic Idea

- Intersect scan lines with edges
- Find ranges along *x*
- Fill interior of those ranges

Use coherence to speed up



The *x*-value of an intersection with one scan line is close to the intersection with the previous one

General Polygons – Data Structures

- Edge: $(x_i, y_i) \rightarrow (x_{i+1}, y_{i+1})$

Edge
maxY
currentX
xIncr

$$maxY: \quad \max(y_i, y_{i+1})$$

$$currentX: \begin{cases} x_i, & y_i = \min(y_i, y_{i+1}) \\ x_{i+1}, & otherwise \end{cases}$$

$$xIncr: \quad \frac{x_{i+1} - x_i}{y_{i+1} - y_i}$$

General Polygons – Data Structures

- Edge: $(x_i, y_i) \rightarrow (x_{i+1}, y_{i+1})$

Edge
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$$maxY: \quad \max(y_i, y_{i+1})$$

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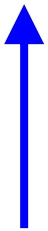
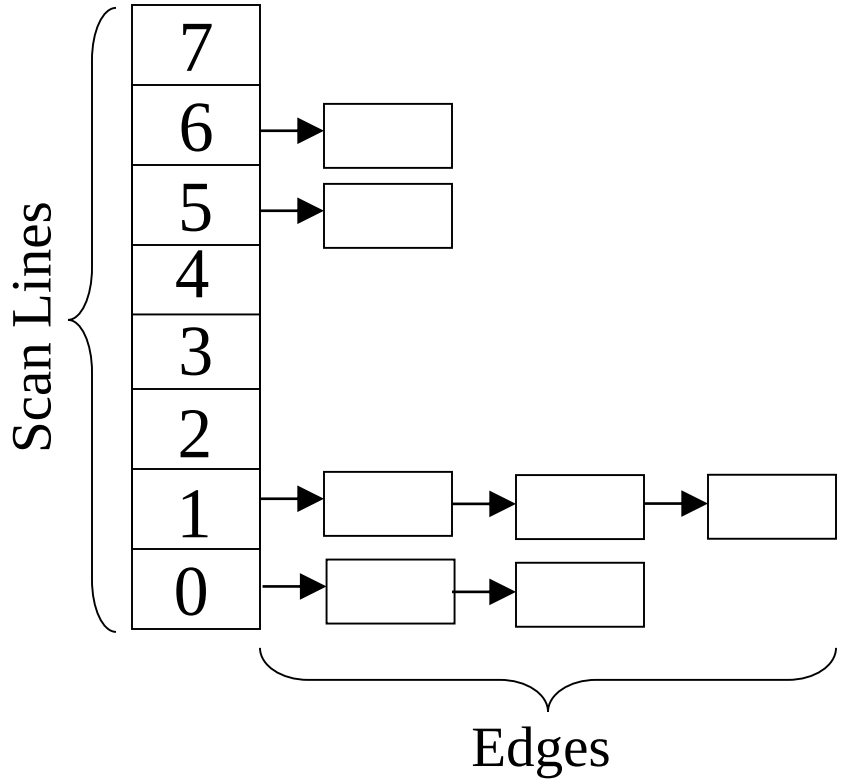


Horizontal edges will not be used!!!

General Polygons – Data Structures

- Active Edge Table:

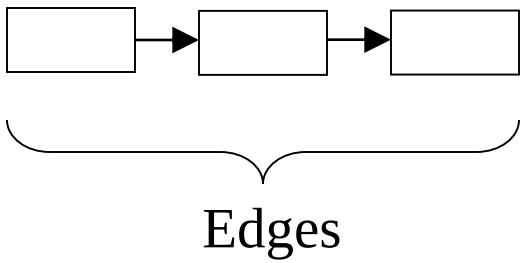


Store a linked-list per scan-line.

Insert edges into table at scan-line associated with lowest end-point.

General Polygons – Data Structures

- Active Edge List:



List of all edges intersecting current scan-line sorted by their *x*-values

General Polygons – Algorithm

line = 0

While (*line* < height)

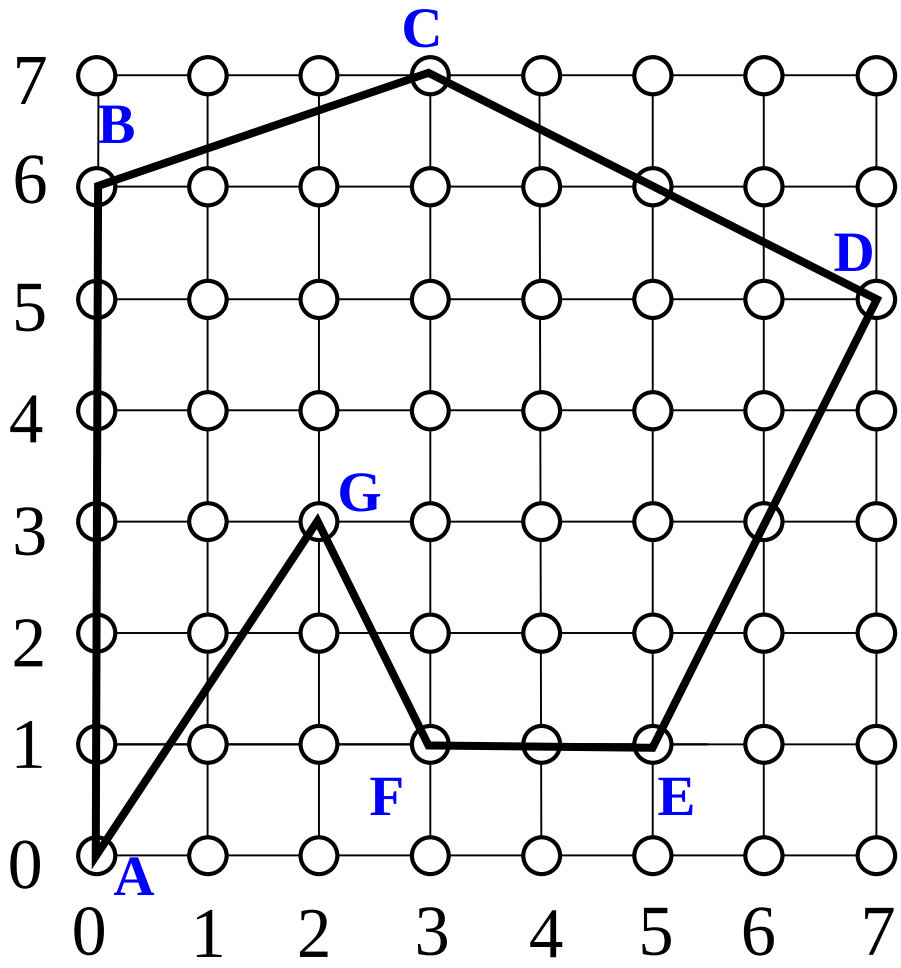
- Add edges to Active Edge List from Active Edge Table starting at *line*
- Remove edges that end at *line*
- Fill pixels
- Increment *x*-values on edges in Active Edge List
- Increment *line*

General Polygons – Example

Active Edge Table

7
6
5
4
3
2
1
0

Active Edge List

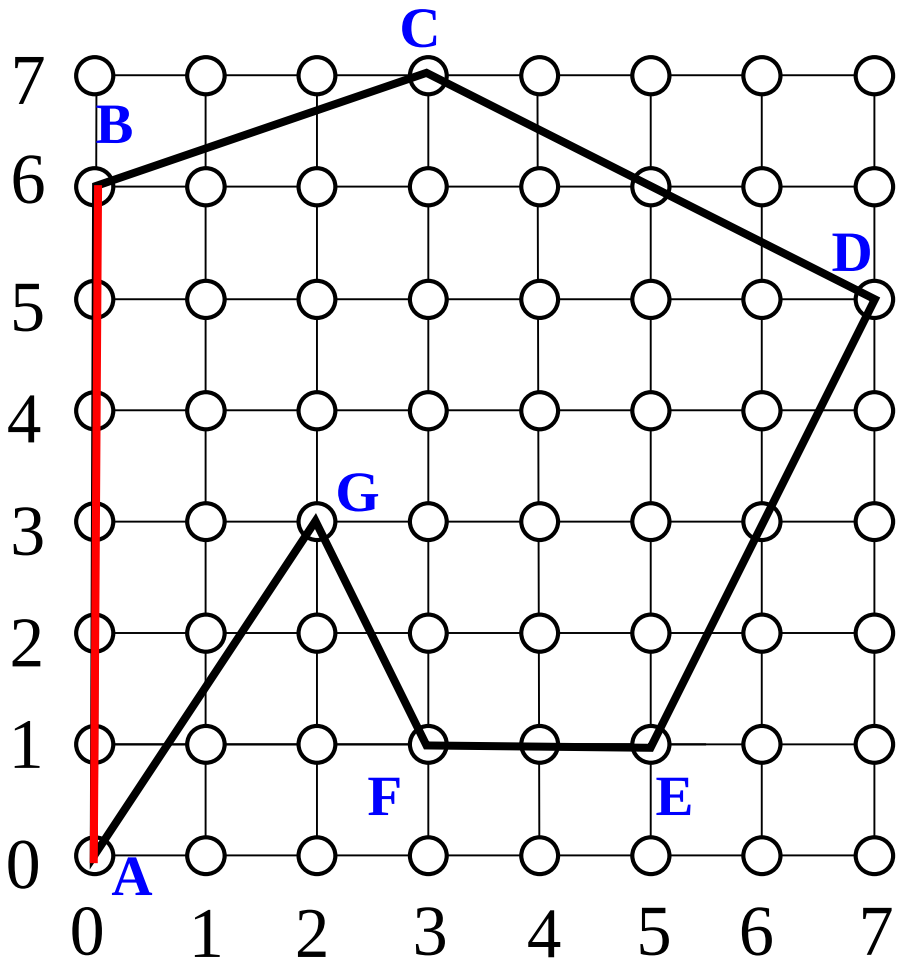


General Polygons – Example

Active Edge Table

7	
6	
5	
4	
3	
2	
1	
0	→ AB

Active Edge List

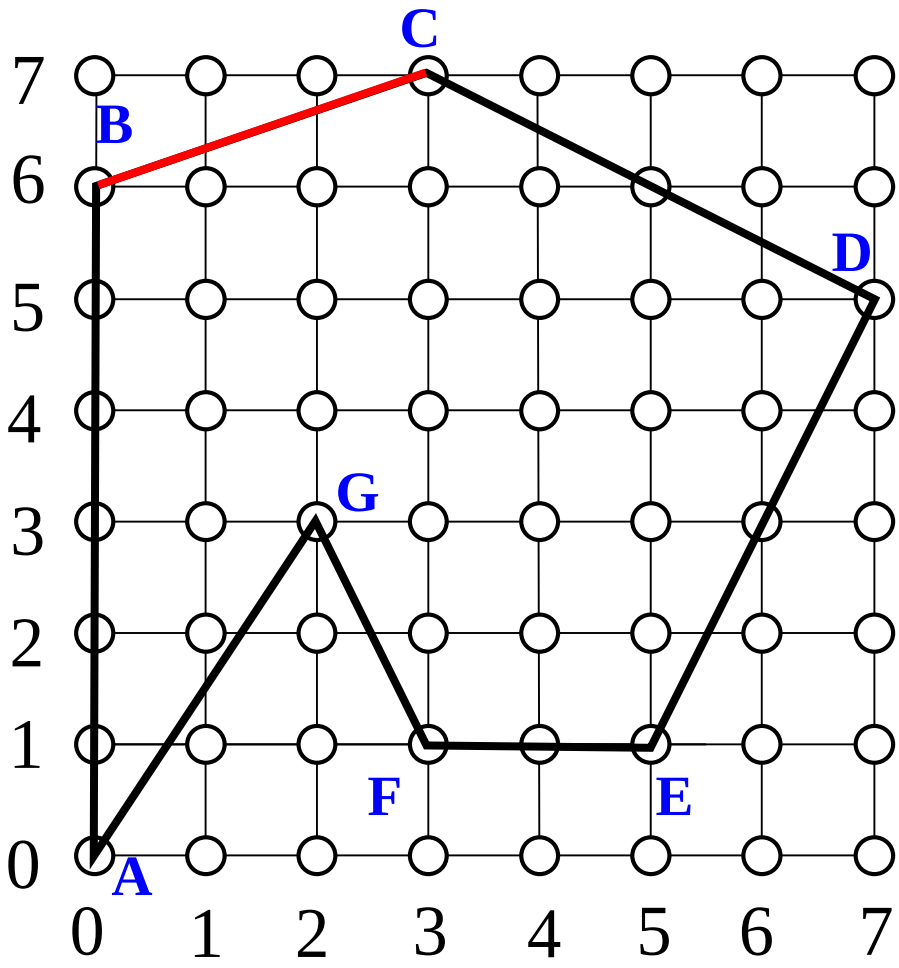


General Polygons – Example

Active Edge Table

7	
6	→ BC
5	
4	
3	
2	
1	
0	→ AB

Active Edge List

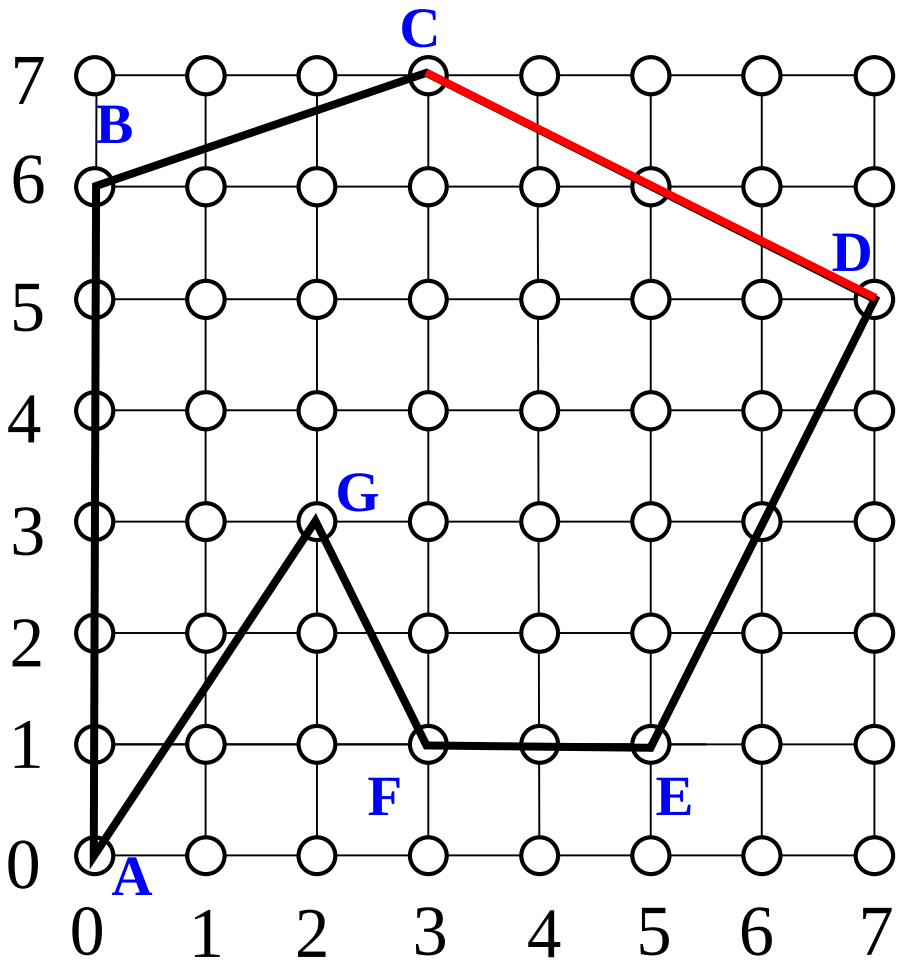


General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	
0	AB

Active Edge List

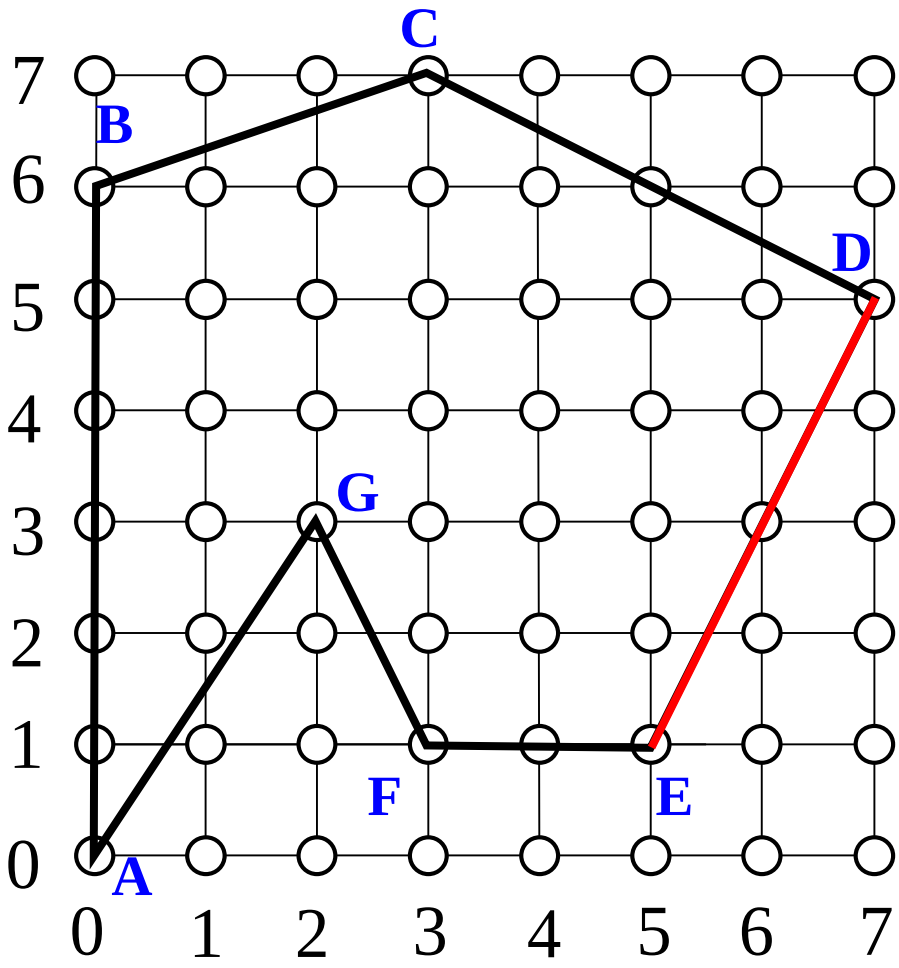


General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	ED
0	AB

Active Edge List

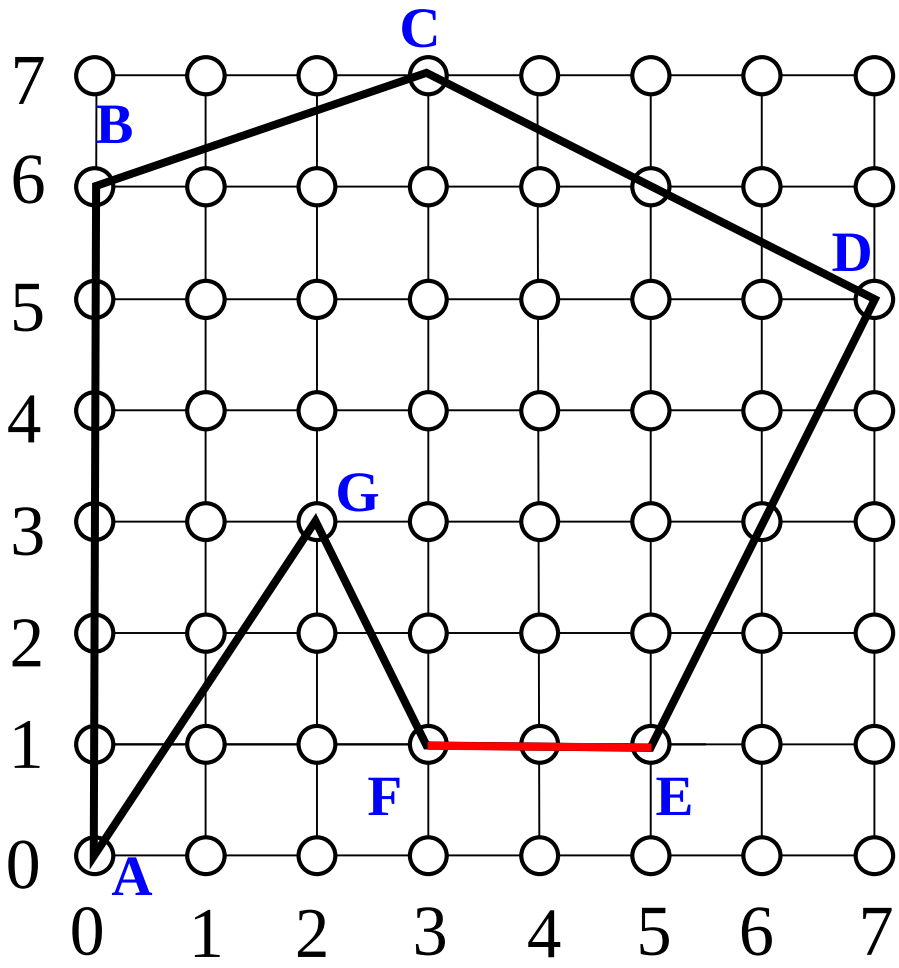


General Polygons – Example

Active Edge Table

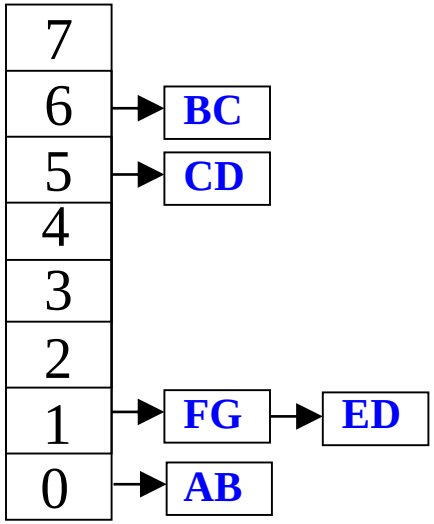
7	
6	BC
5	CD
4	
3	
2	
1	ED
0	AB

Active Edge List

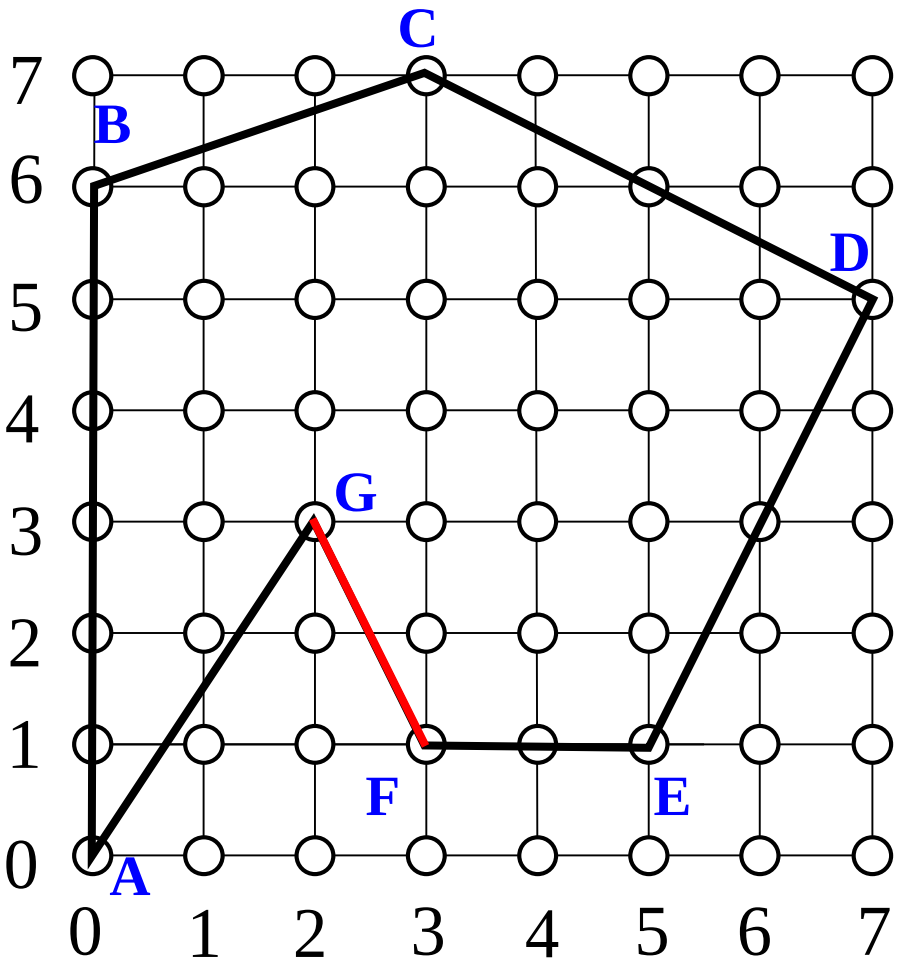


General Polygons – Example

Active Edge Table



Active Edge List

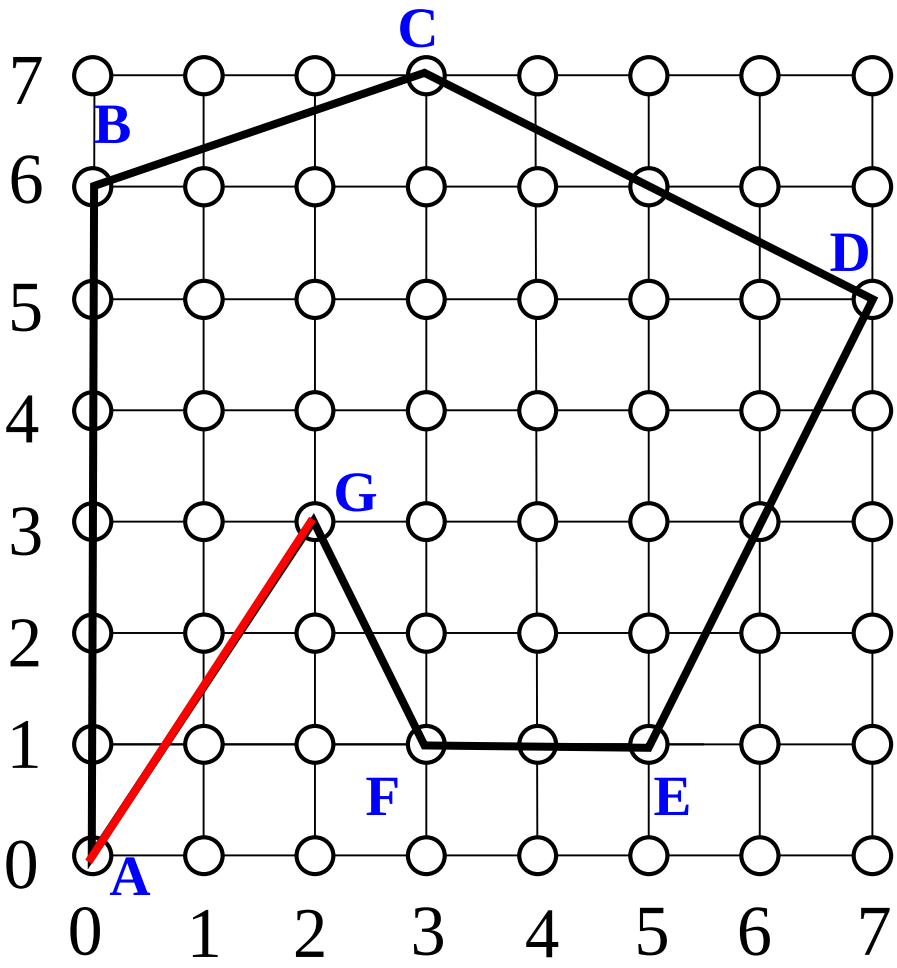


General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List



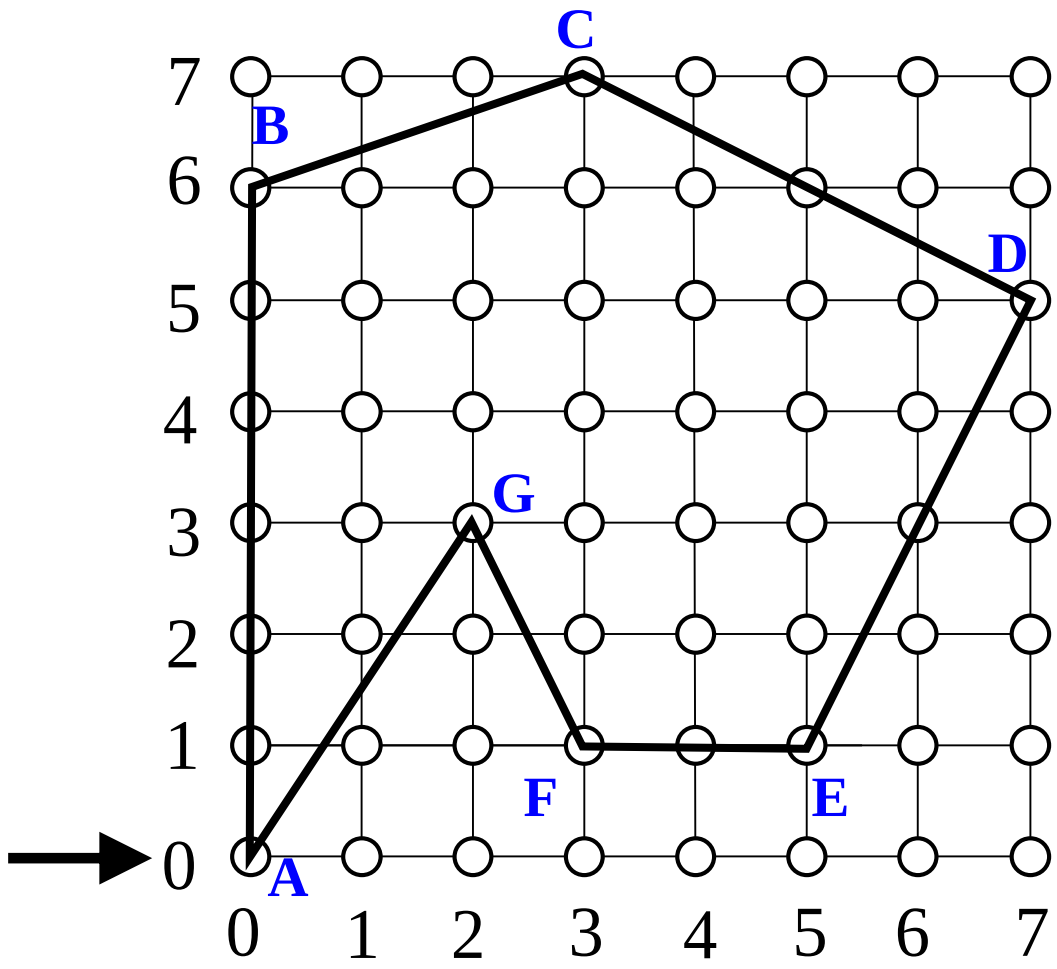
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	AG
maxY	6	3
currentX	0	0
xIncr	0	⅔



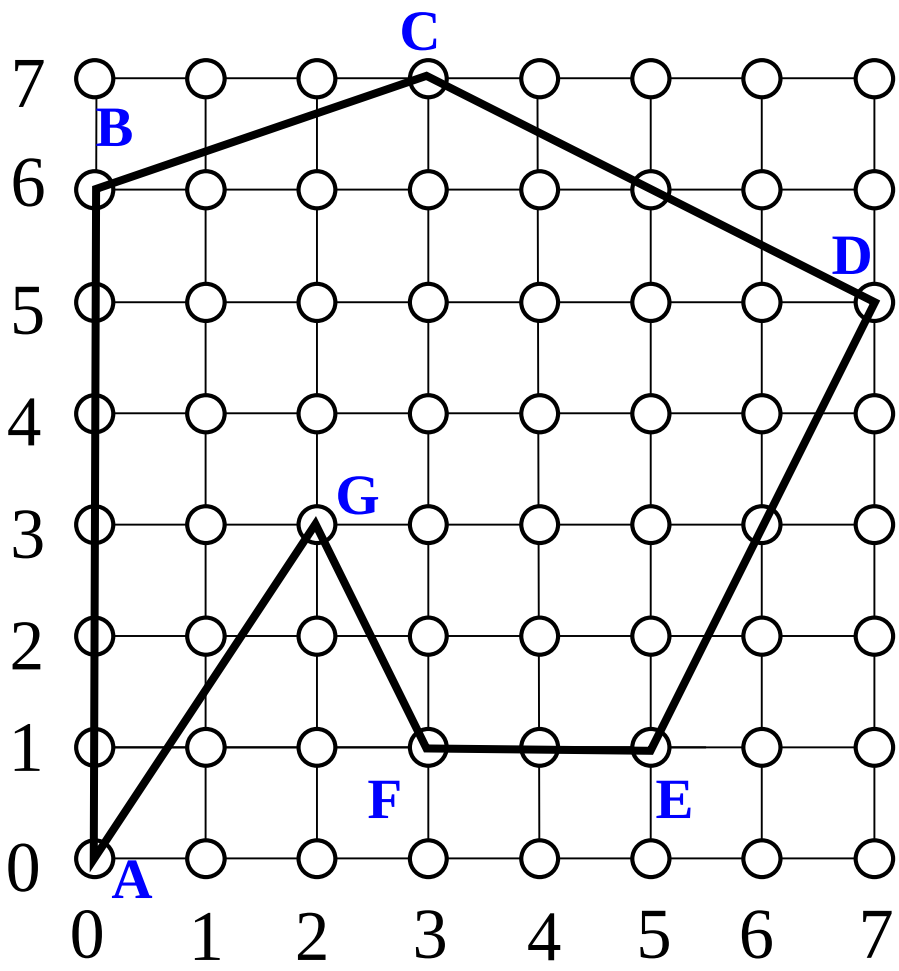
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	AG	FG	ED
maxY	6	3	3	5
currentX	0	$\frac{2}{3}$	3	5
xIncr	0	$\frac{2}{3}$	$-\frac{1}{2}$	$\frac{1}{2}$



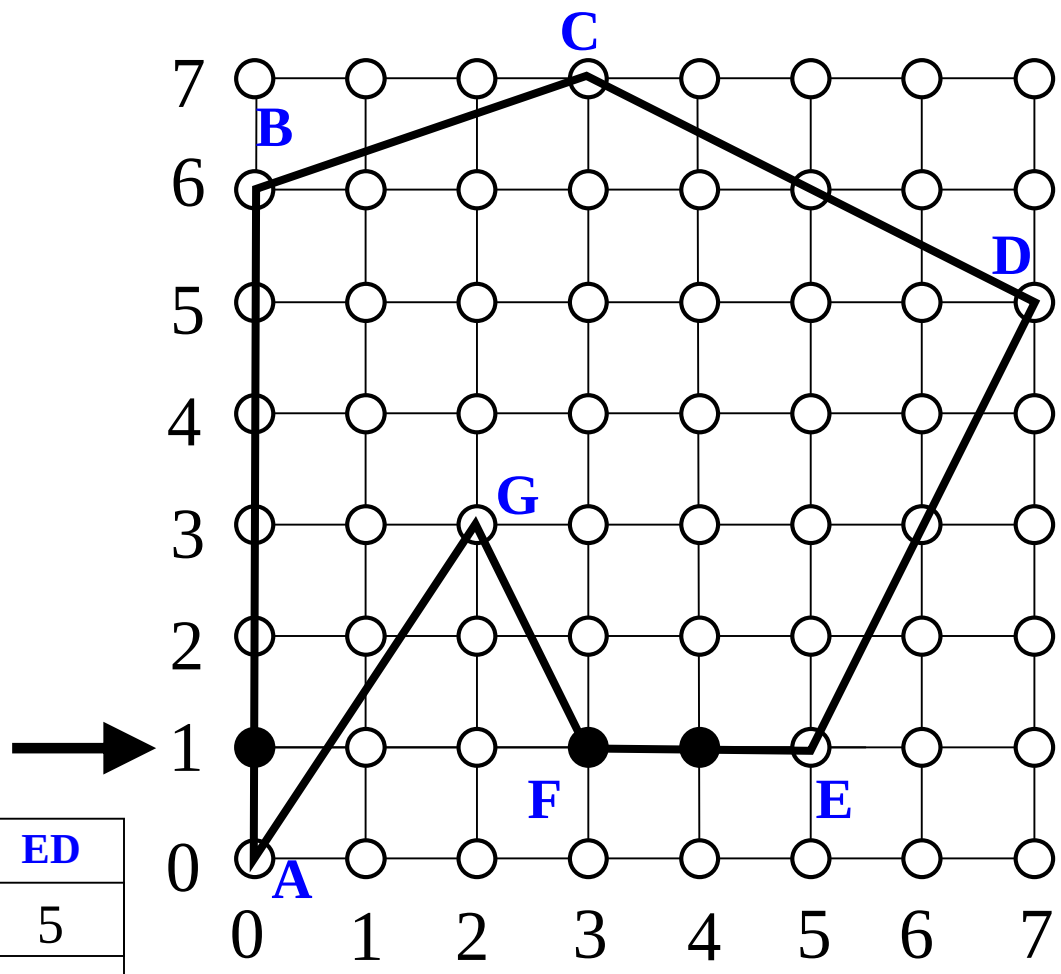
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

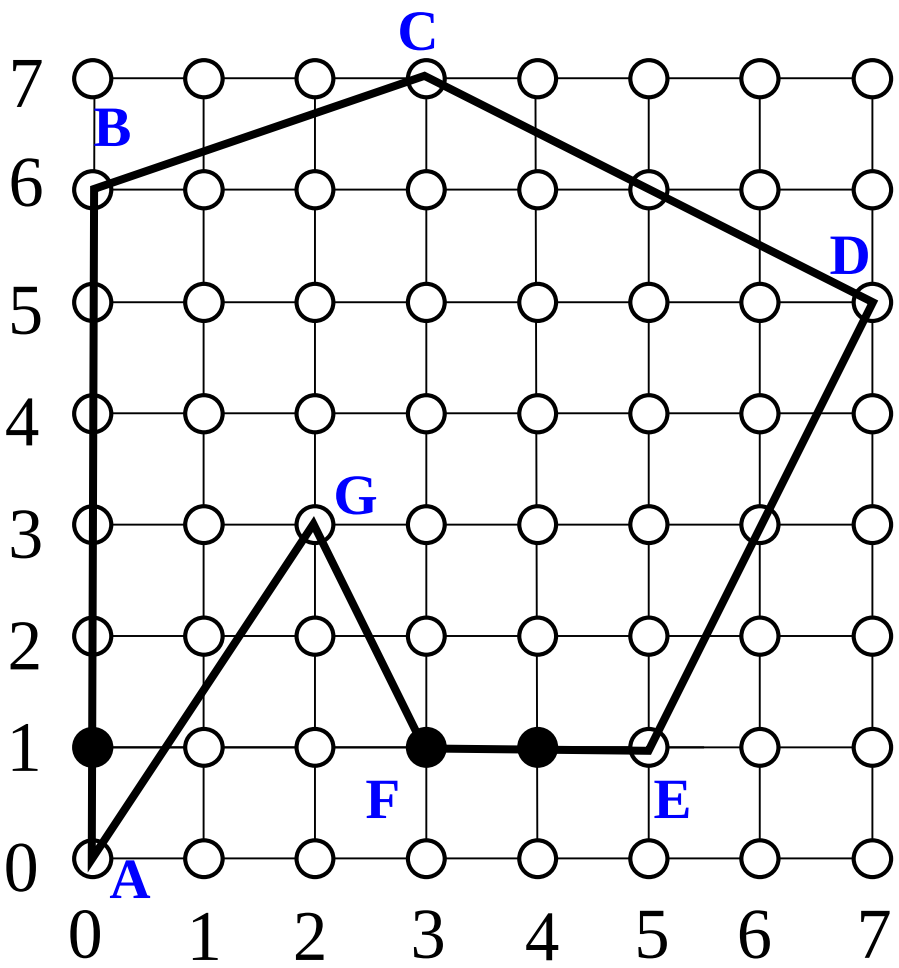
	AB	AG	FG	ED
maxY	6	3	3	5
currentX	0	$\frac{2}{3}$	3	5
xIncr	0	$\frac{2}{3}$	$-\frac{1}{2}$	$\frac{1}{2}$



General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG



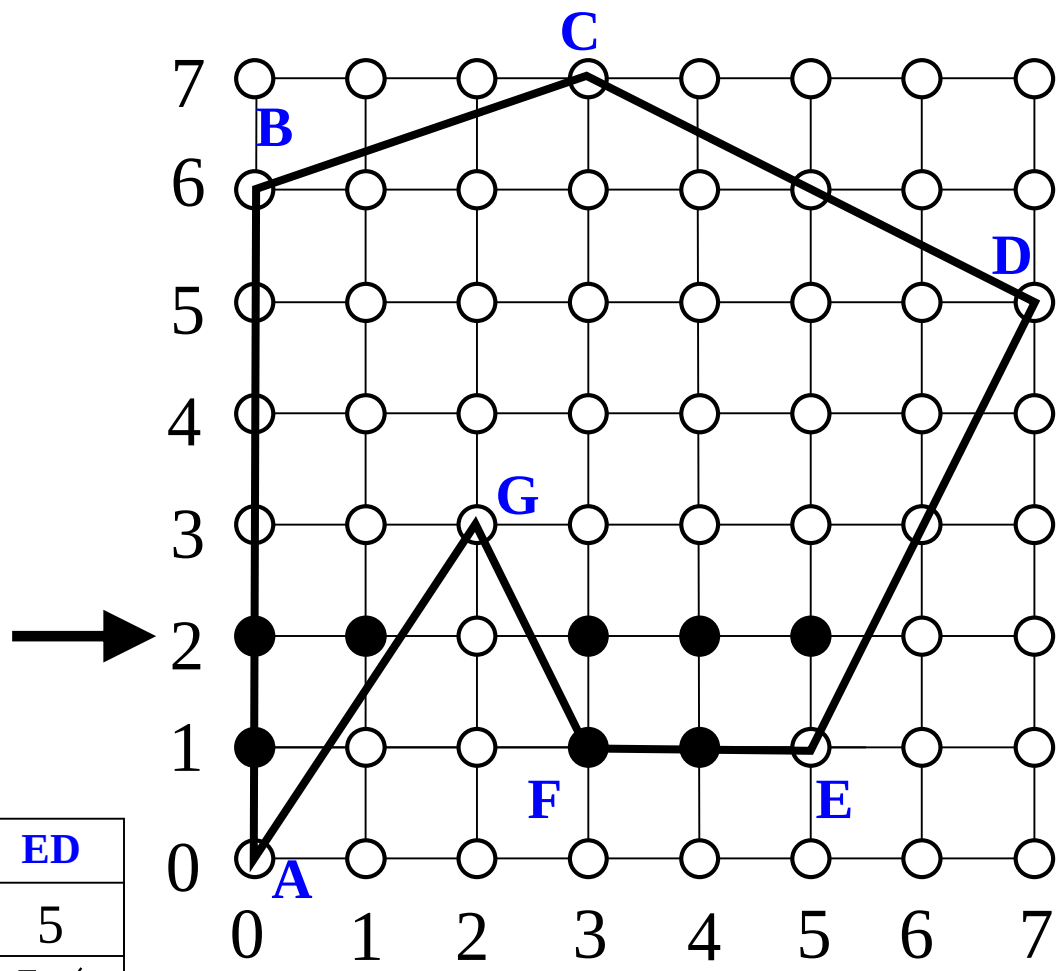
Active Edge List

	AB	AG	FG	ED
maxY	6	3	3	5
currentX	0	$\frac{4}{3}$	$2\frac{1}{2}$	$5\frac{1}{2}$
xIncr	0	$\frac{2}{3}$	$-\frac{1}{2}$	$\frac{1}{2}$

General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG



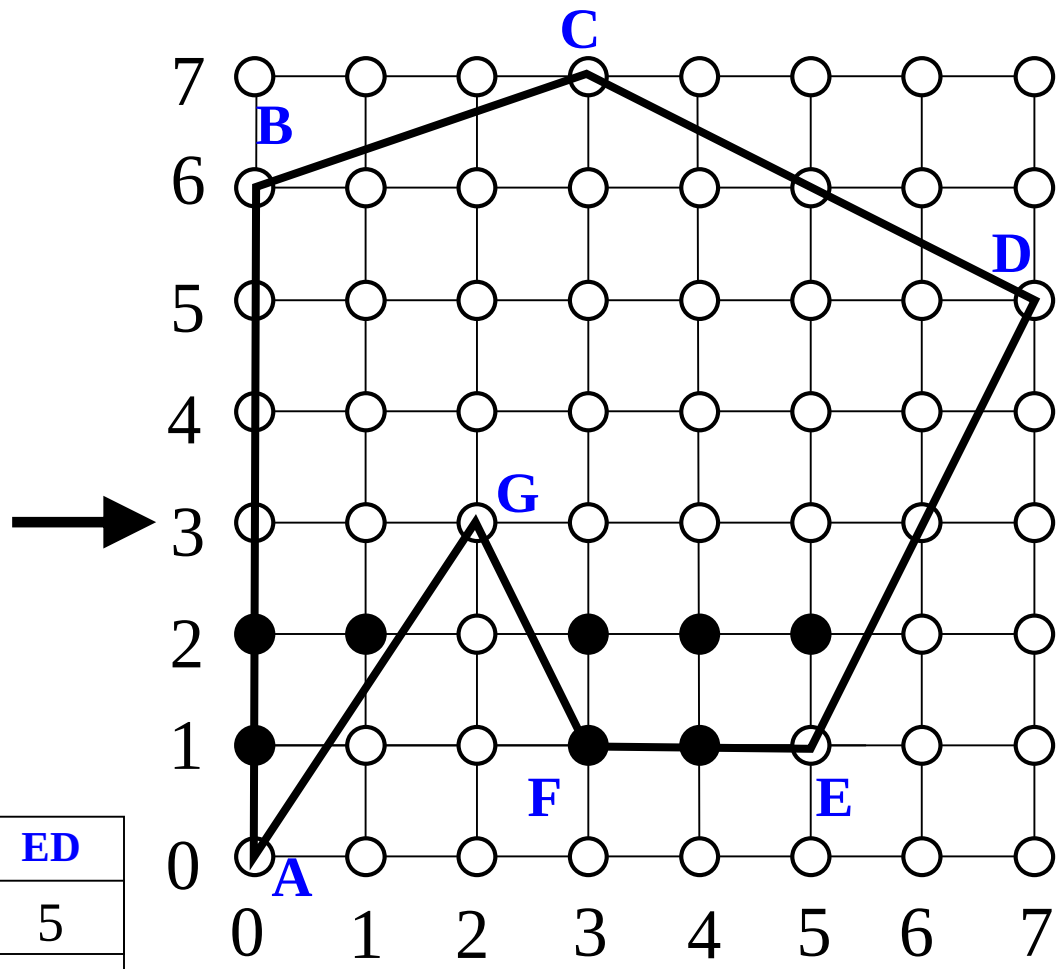
Active Edge List

	AB	AG	FG	ED
maxY	6	3	3	5
currentX	0	$\frac{4}{3}$	$2\frac{1}{2}$	$5\frac{1}{2}$
xIncr	0	$\frac{2}{3}$	$-\frac{1}{2}$	$\frac{1}{2}$

General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG



Active Edge List

	AB	~~AG~~	~~FG~~	ED
maxY	6	~~3~~	~~3~~	5
currentX	0	~~2~~	~~2~~	6
xIncr	0	~~$\frac{2}{3}$~~	~~$-\frac{1}{2}$~~	$\frac{1}{2}$

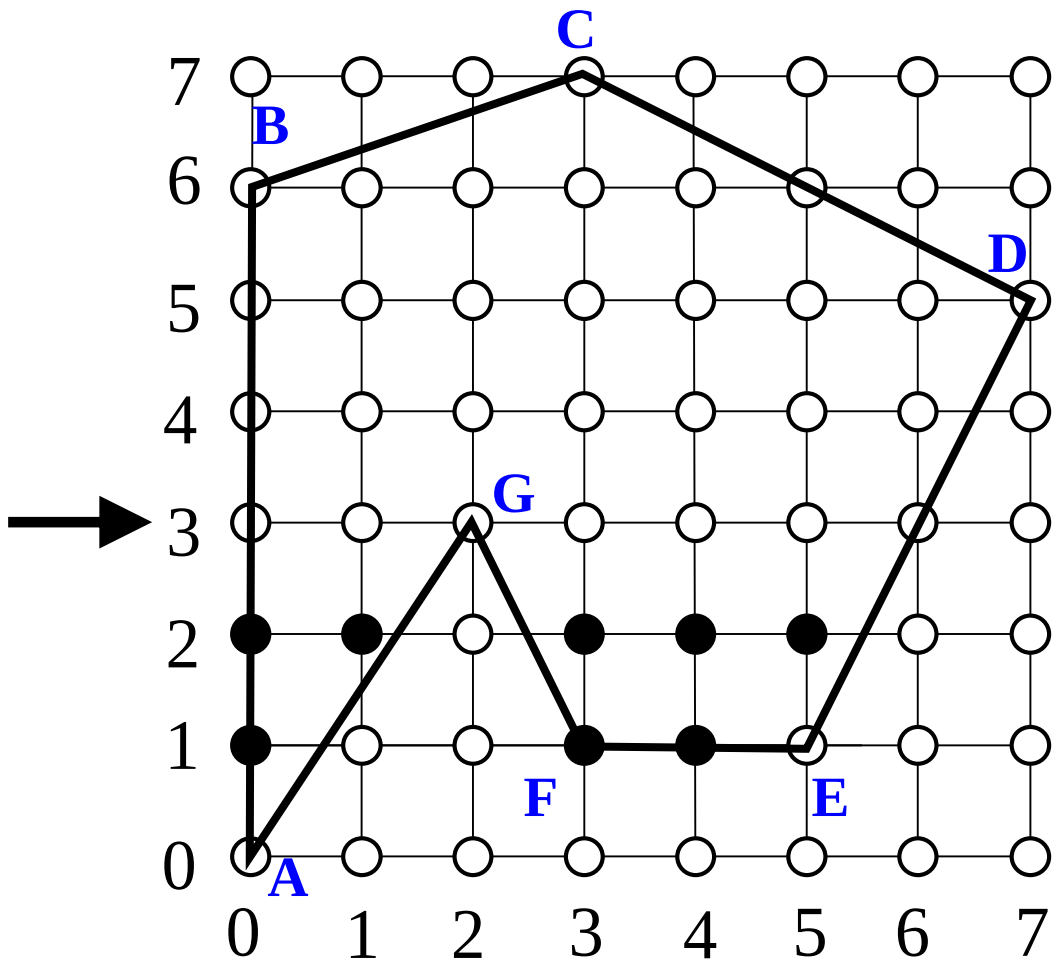
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED
maxY	6	5
currentX	0	6
xIncr	0	½



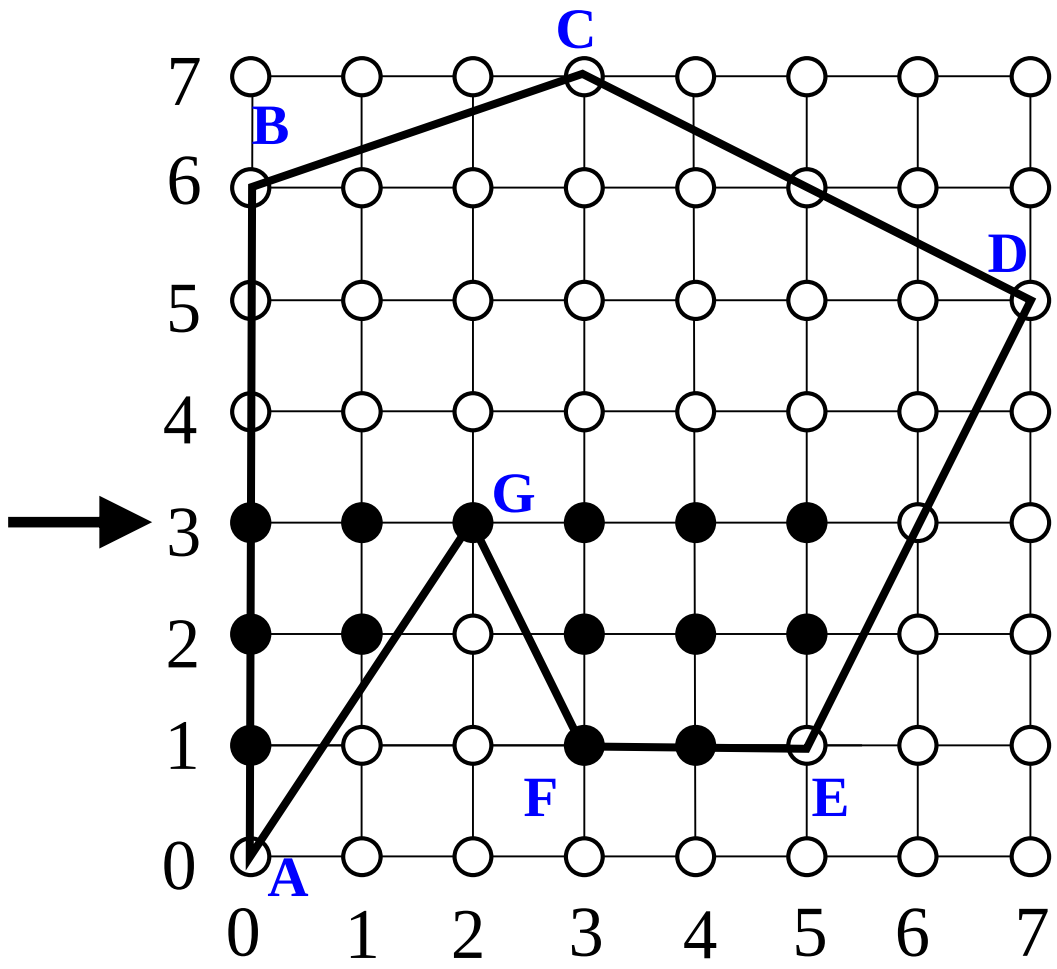
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED
maxY	6	5
currentX	0	6
xIncr	0	½



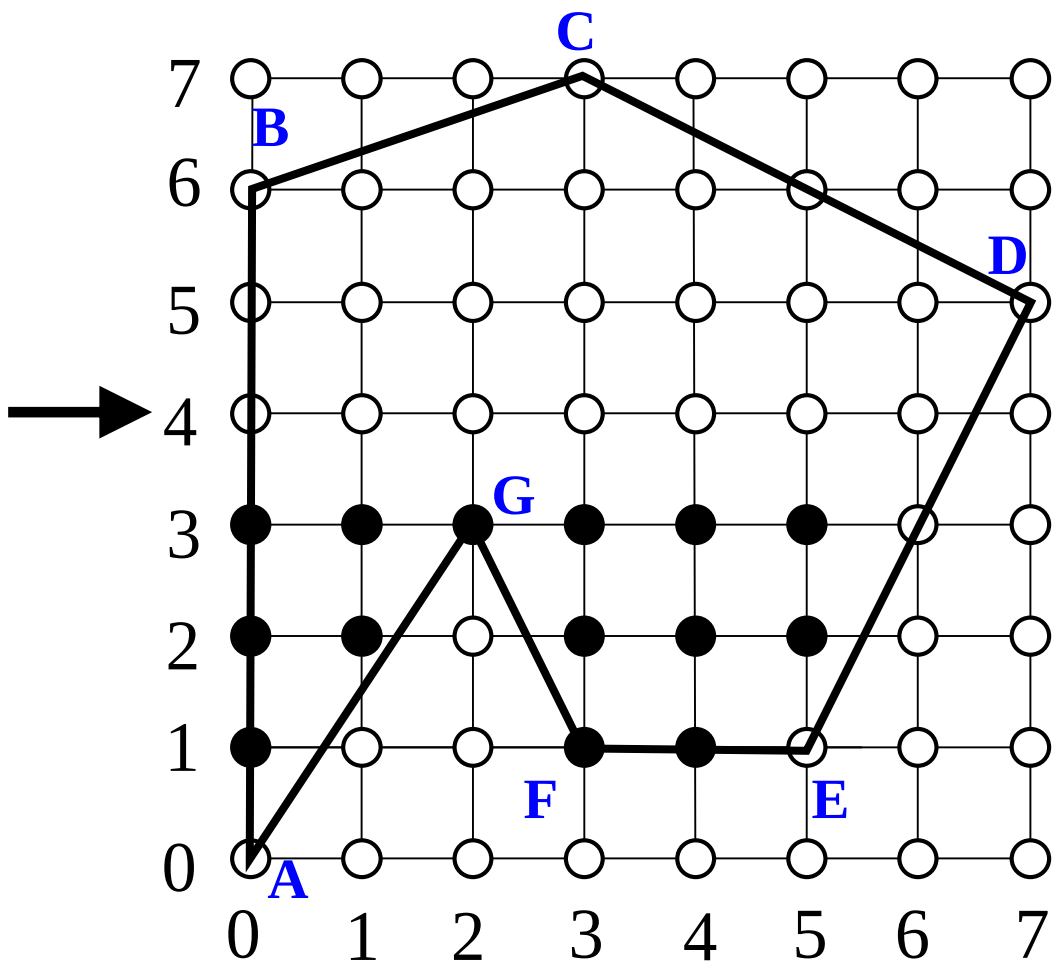
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED
maxY	6	5
currentX	0	6½
xIncr	0	½



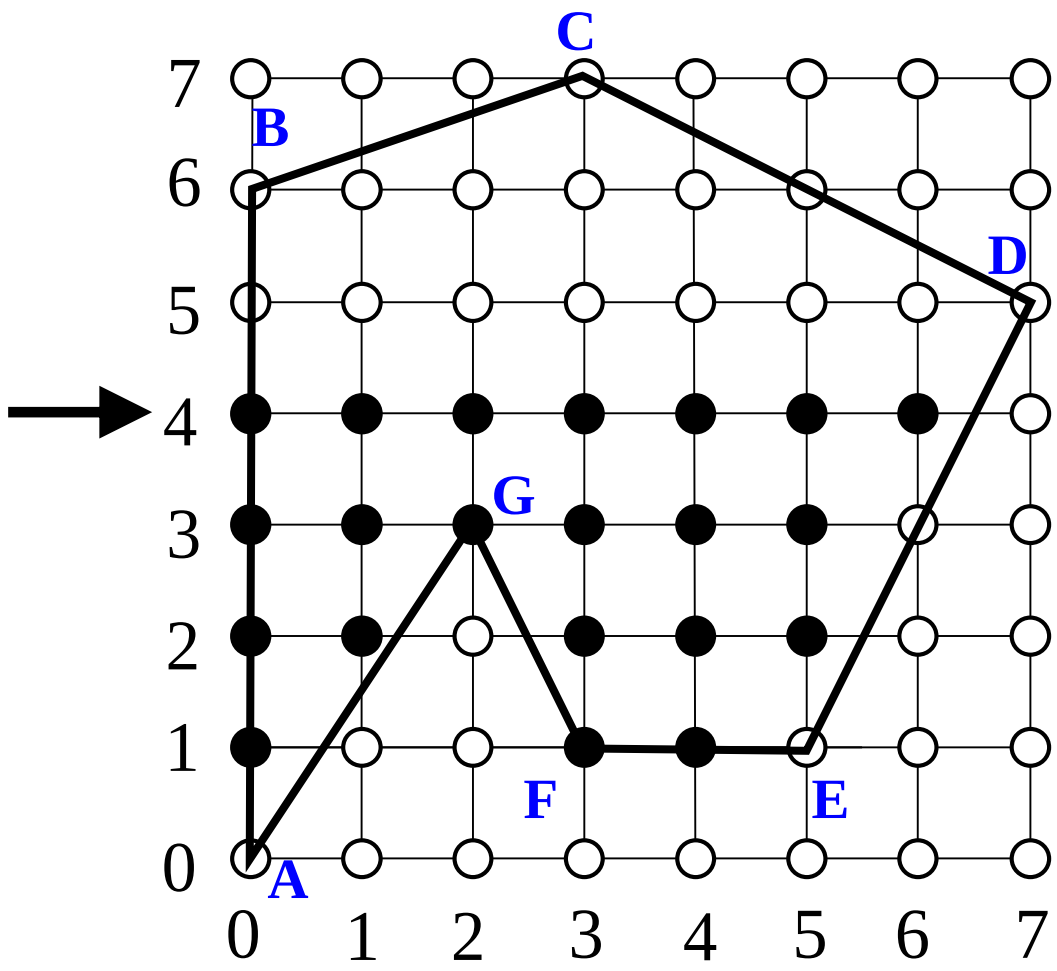
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED
maxY	6	5
currentX	0	6½
xIncr	0	½



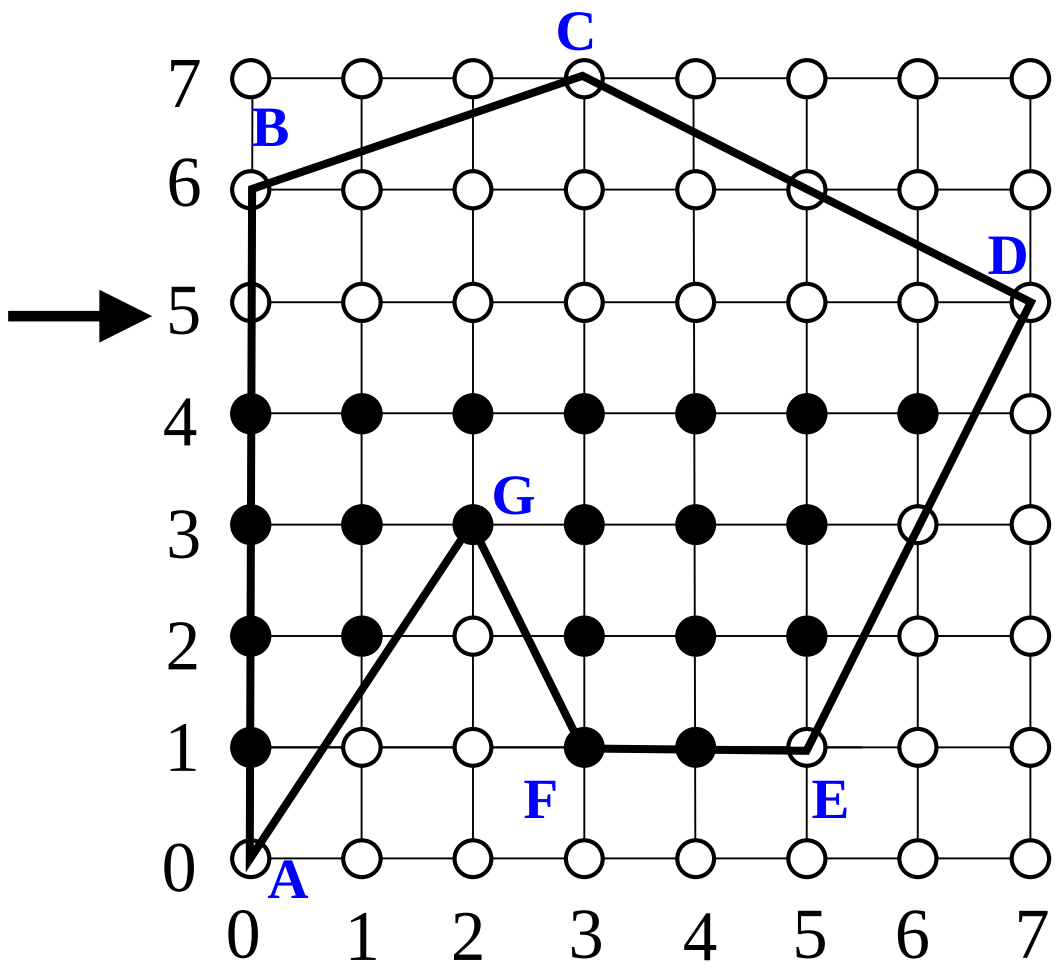
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED	CD
maxY	6	5	7
currentX	0	7	7
xIncr	0	½	−2



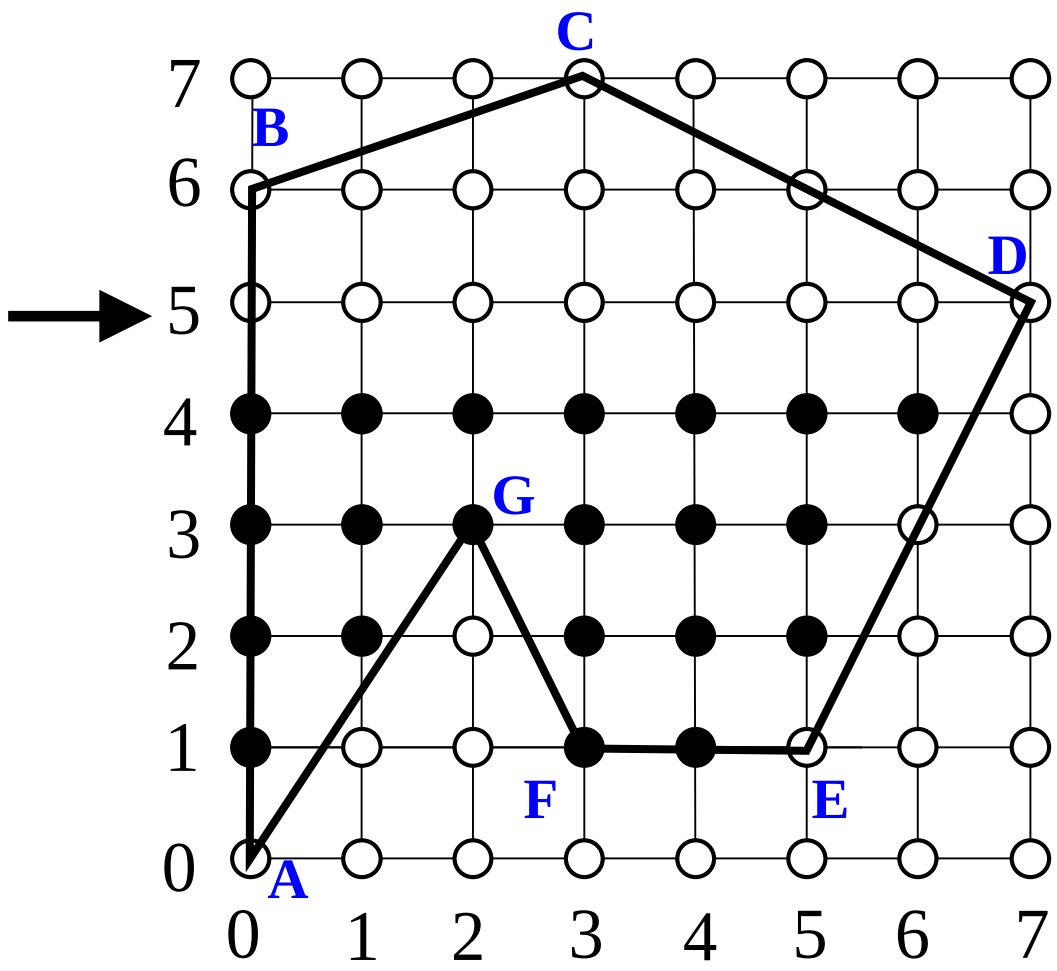
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	ED	CD
maxY	6	5	7
currentX	0	6½	7
xIncr	0	½	−2



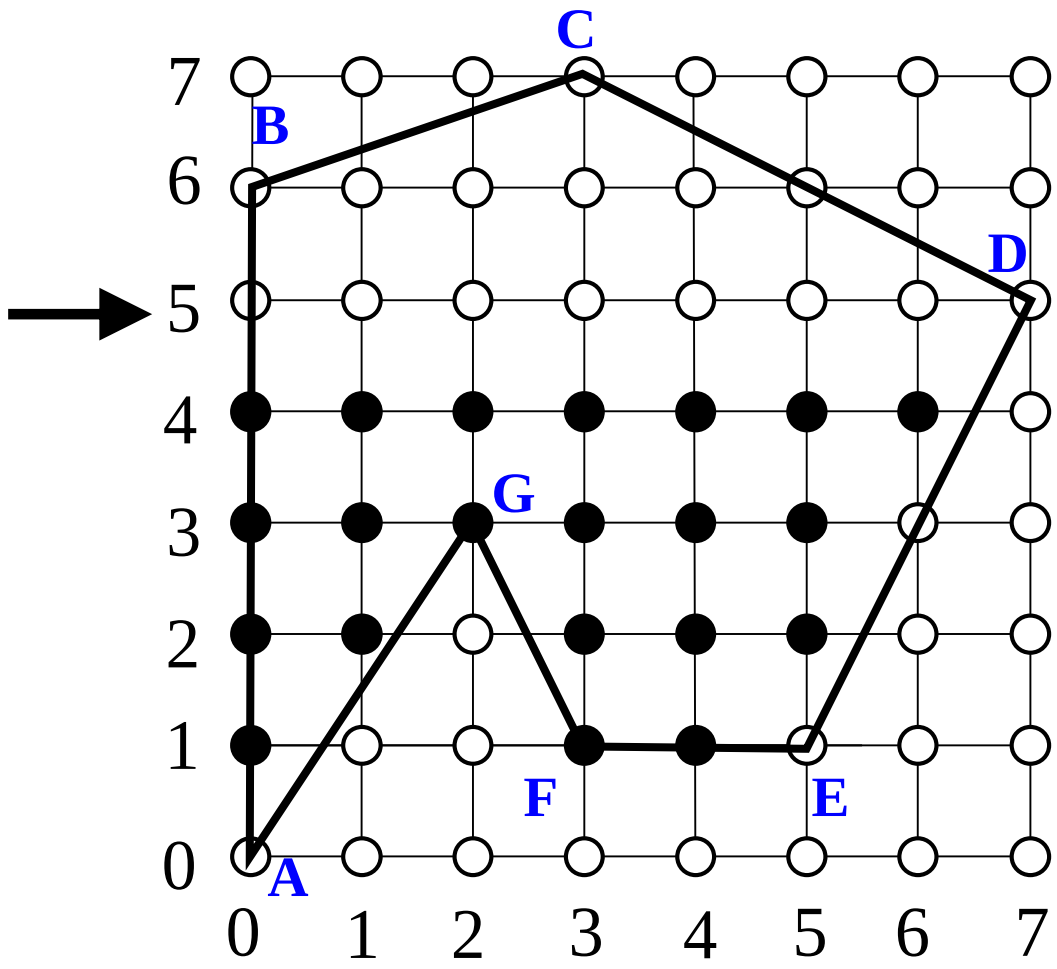
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	CD
maxY	6	7
currentX	0	7
xIncr	0	−2



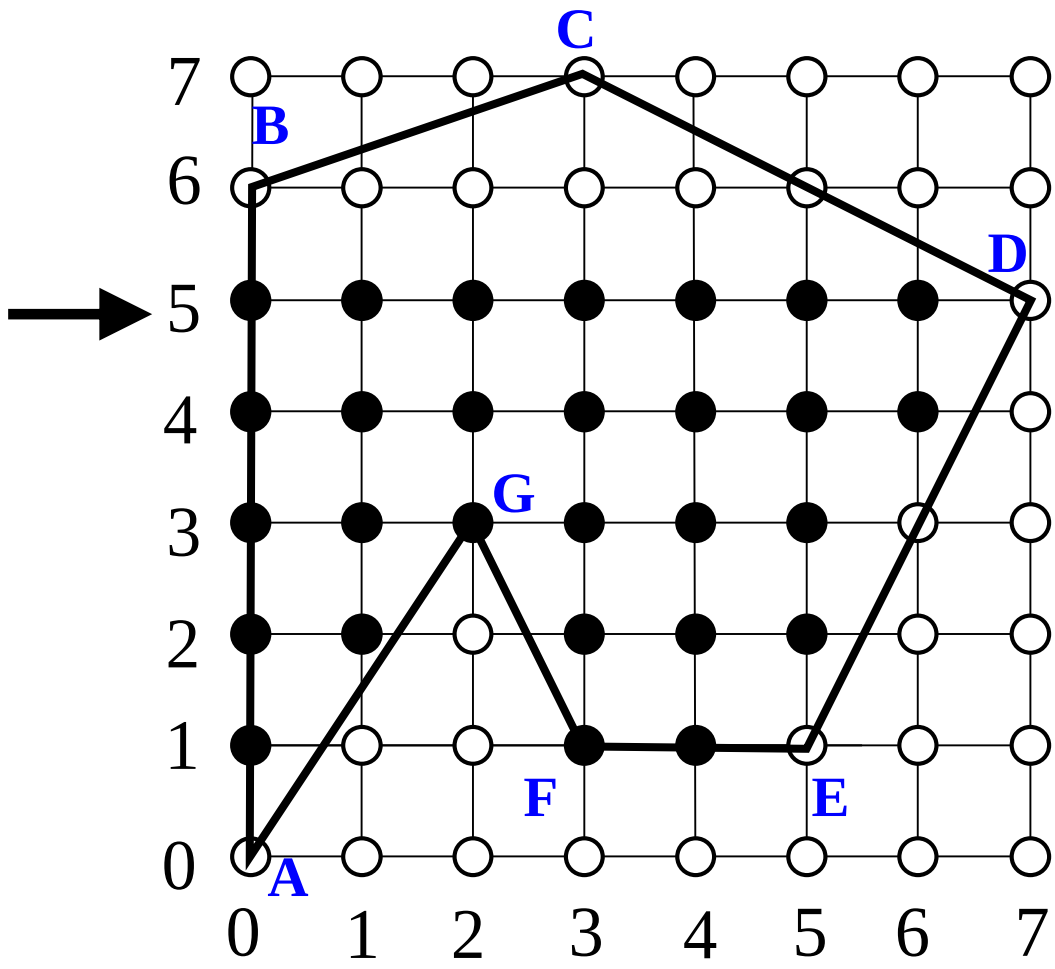
General Polygons – Example

Active Edge Table

7	
6	→ BC
5	→ CD
4	
3	
2	
1	→ FG → ED
0	→ AB → AG

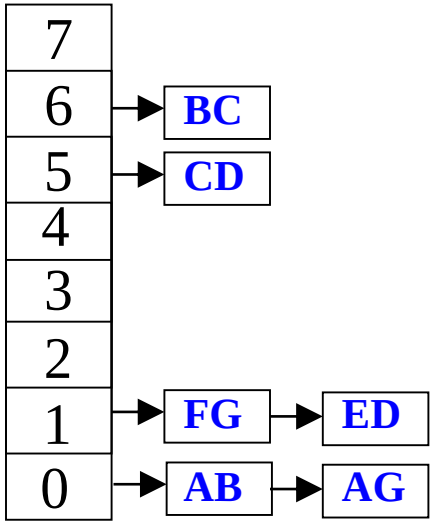
Active Edge List

	AB	CD
maxY	6	7
currentX	0	7
xIncr	0	−2



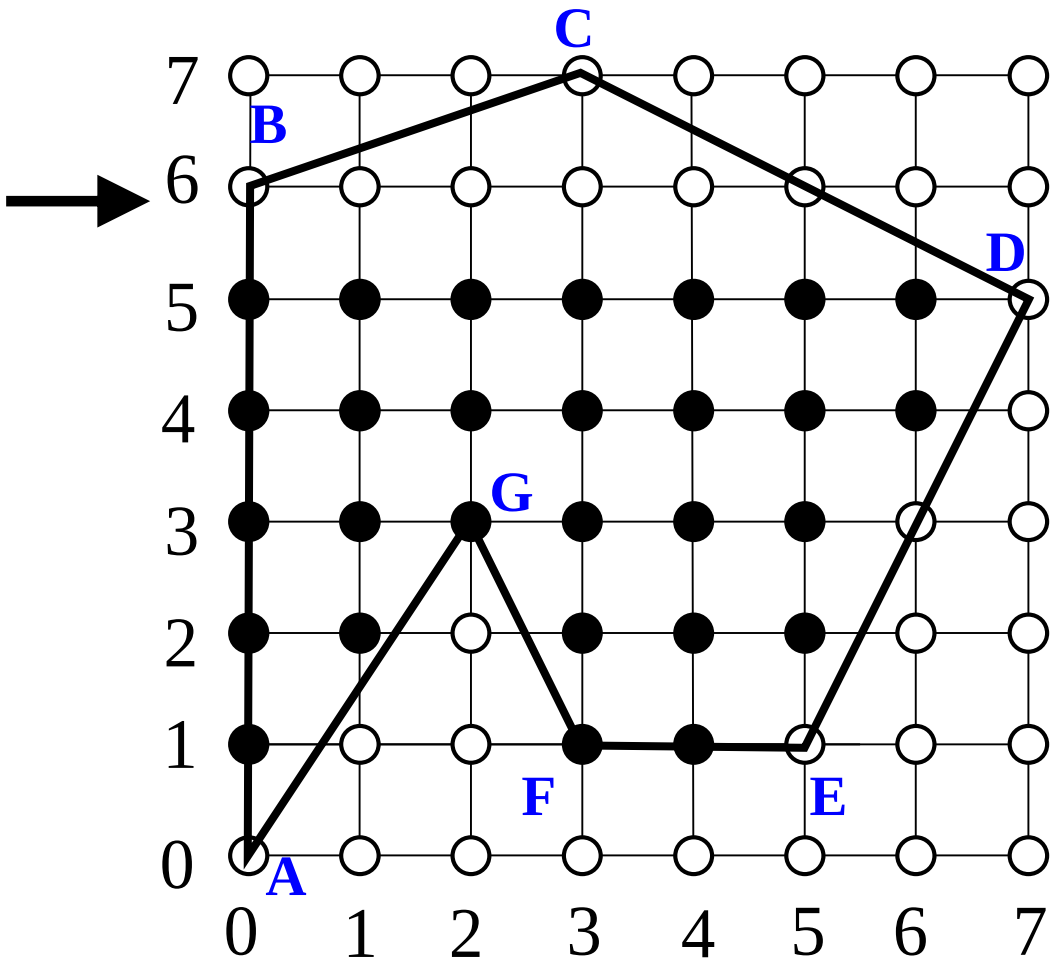
General Polygons – Example

Active Edge Table



Active Edge List

	AB	BC	CD
maxY	6	7	7
currentX	0	0	5
xIncr	0	3	−2



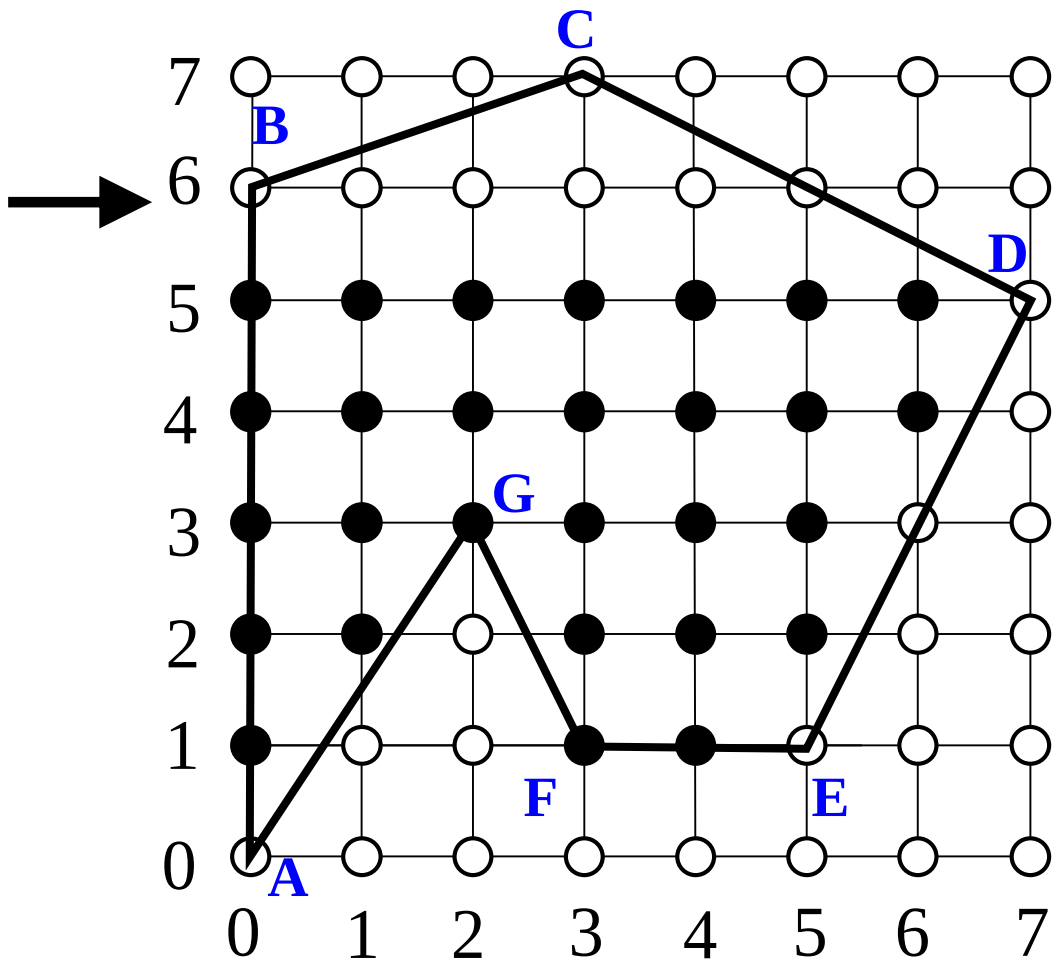
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	AB	BC	CD
maxY	6	7	7
currentX	0	0	5
xIncr	0	3	−2



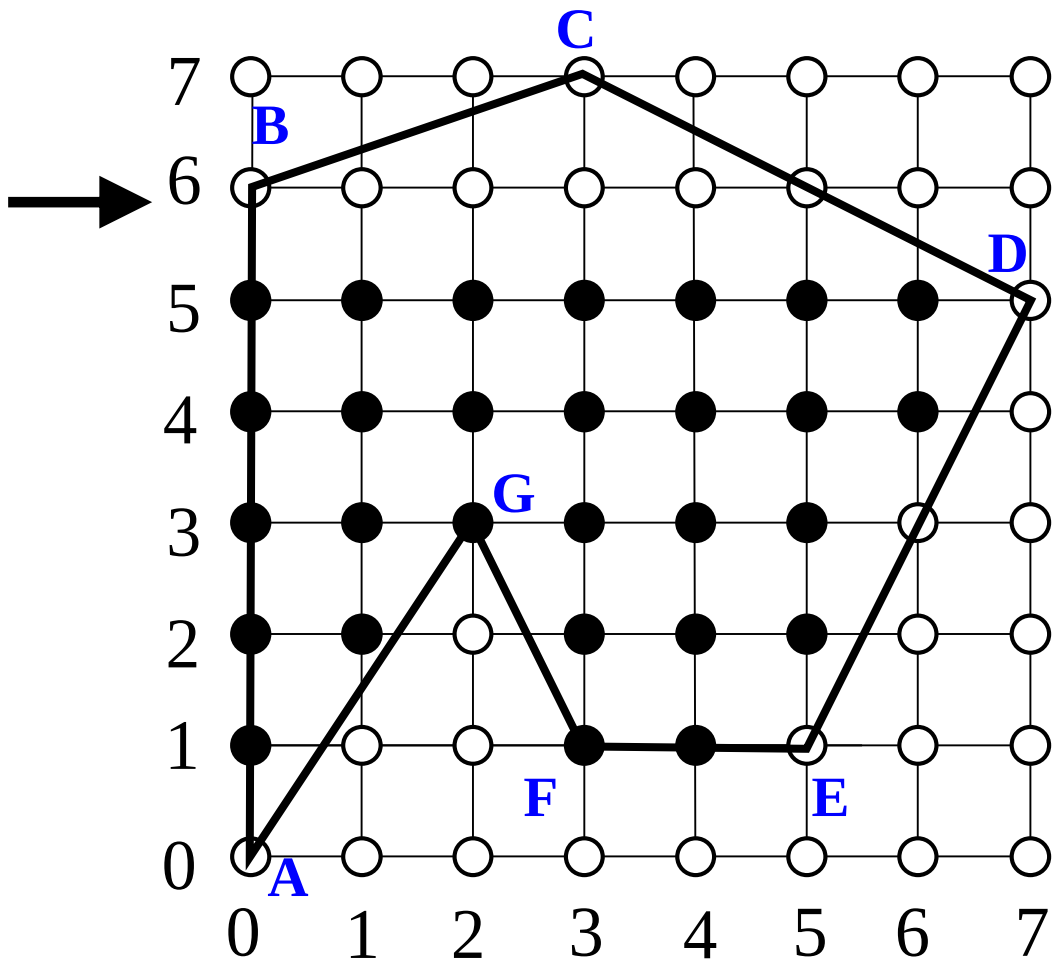
General Polygons – Example

Active Edge Table

7	
6	BC
5	CD
4	
3	
2	
1	FG → ED
0	AB → AG

Active Edge List

	BC	CD
maxY	7	7
currentX	0	5
xIncr	3	−2



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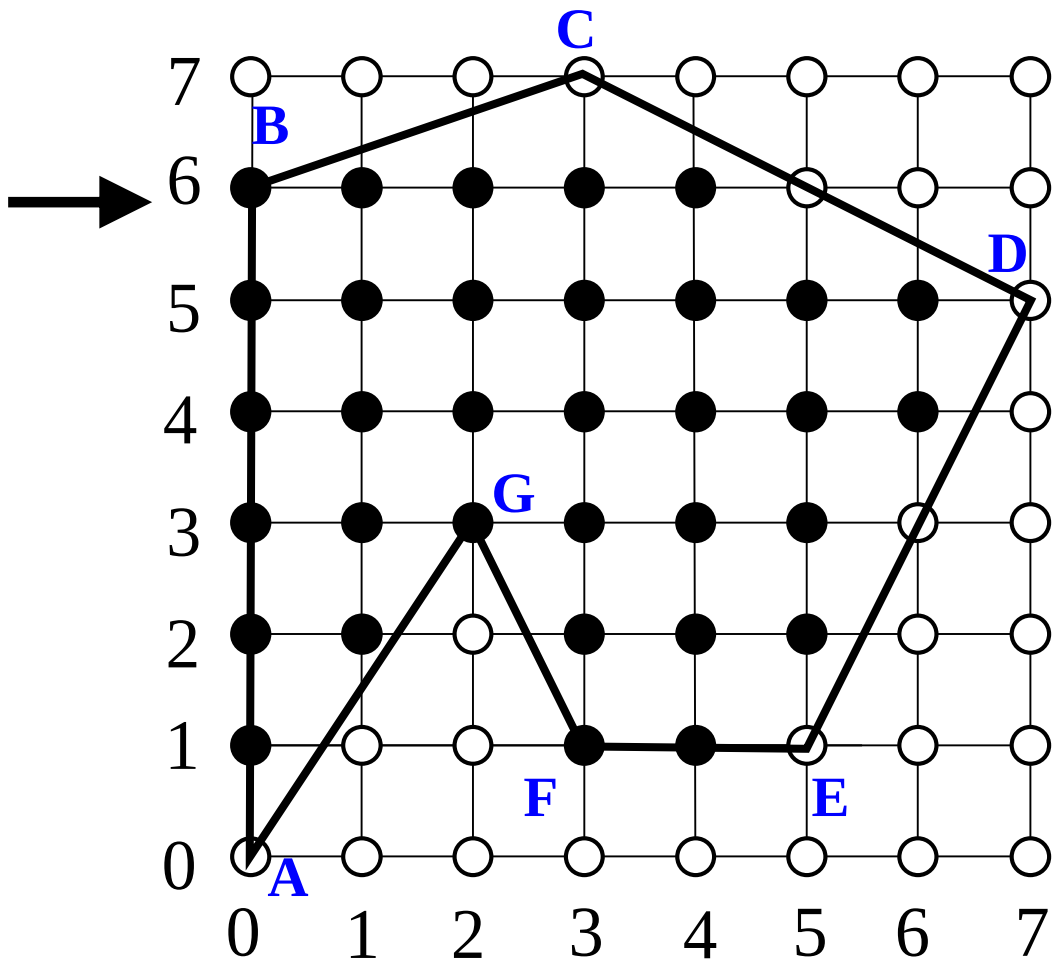
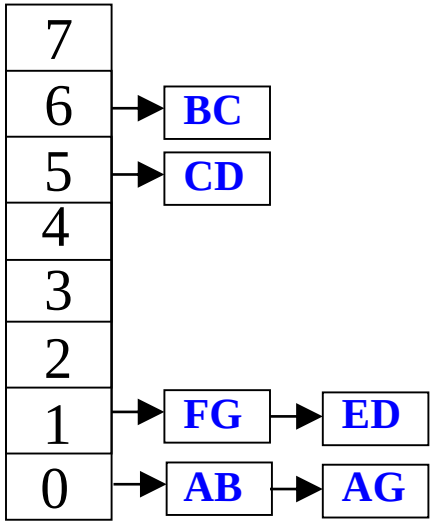
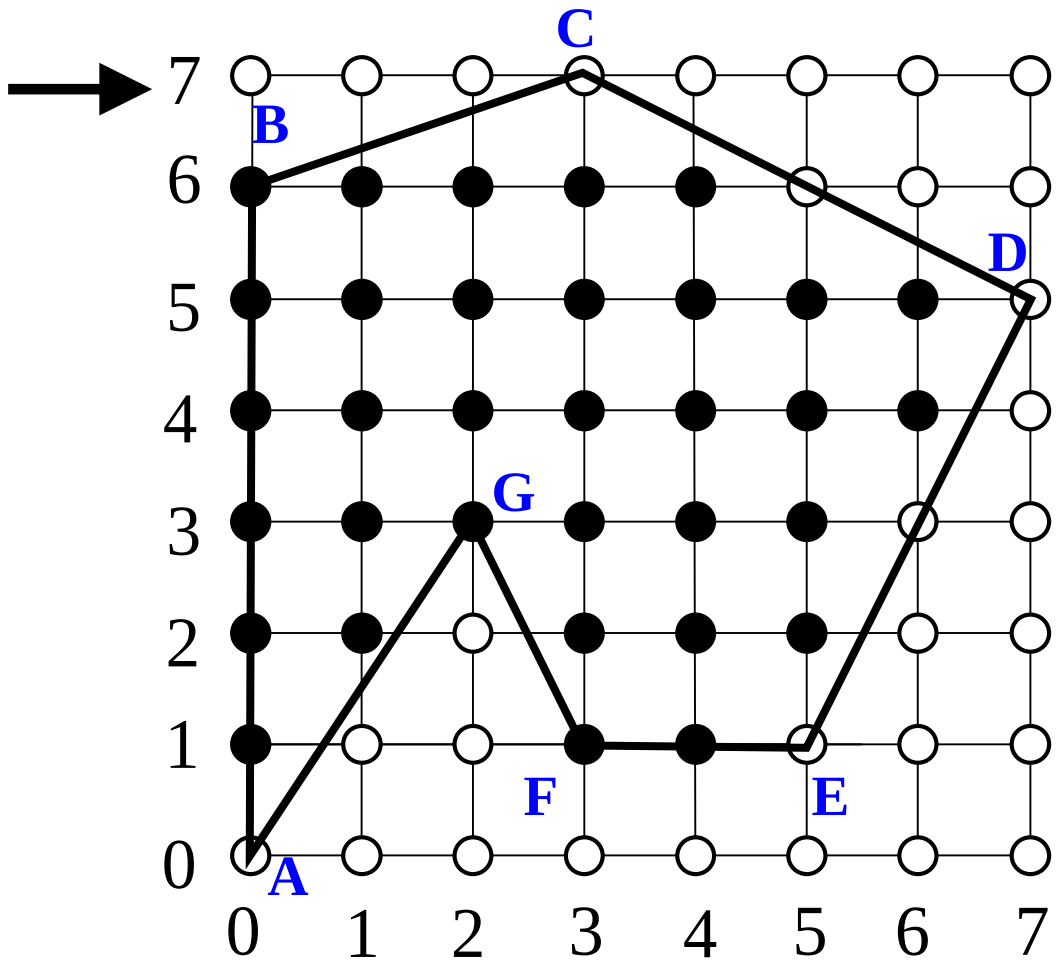


General Polygons – Example

Active Edge Table





Active Edge List

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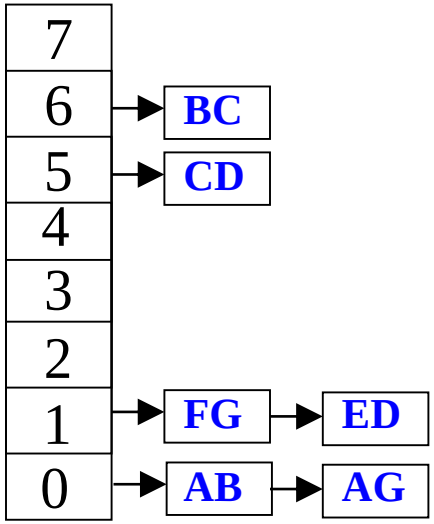
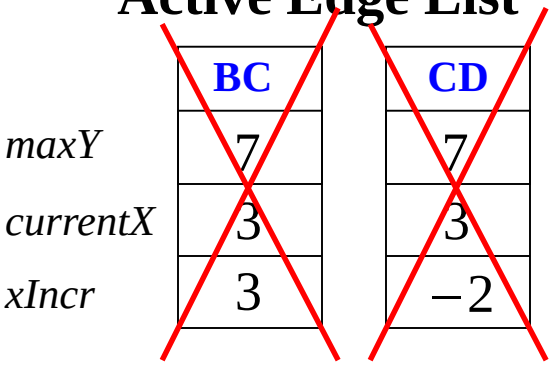
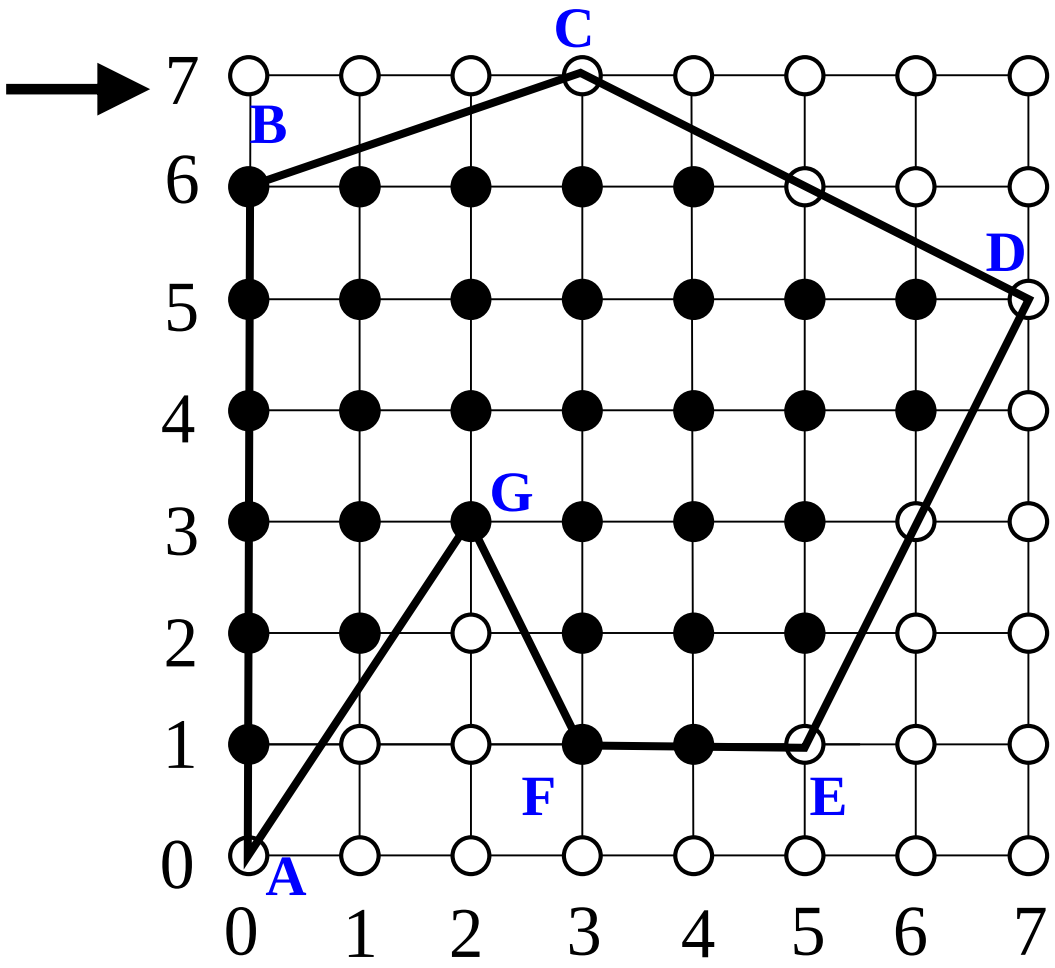
General Polygons – Example

Active Edge Table



Active Edge List

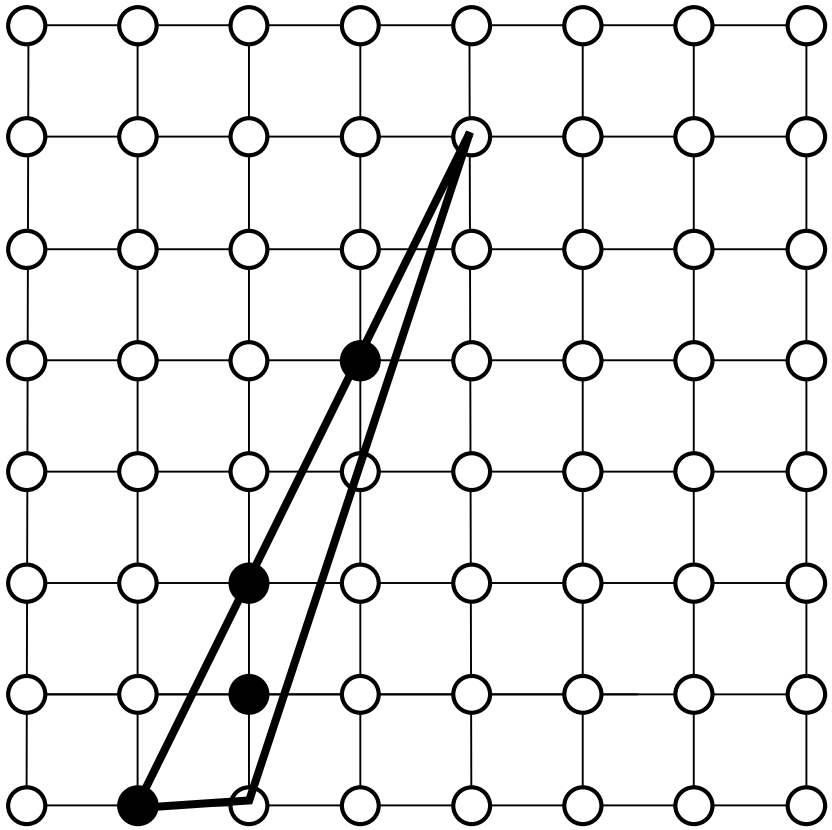




General Polygons – Problems

- Sliver polygons may not be drawn correctly

- No simple solution
- Long, thin triangles cause problems
- Want triangles with good aspect ratio (close to equilateral)

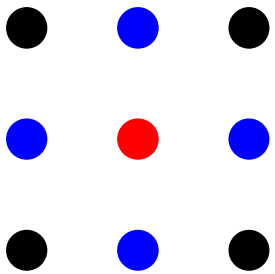


Boundary Fill

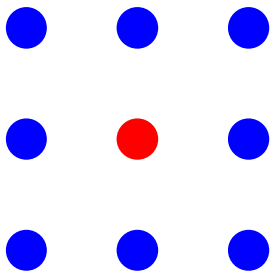
- Start with drawn outline of a polygon and an interior point
- Recursively recolor outward from that point
  - If neighbor different, then recolor and recur
- Everything within the boundary is changed to that color

Boundary Fill

- How to define a neighbor?

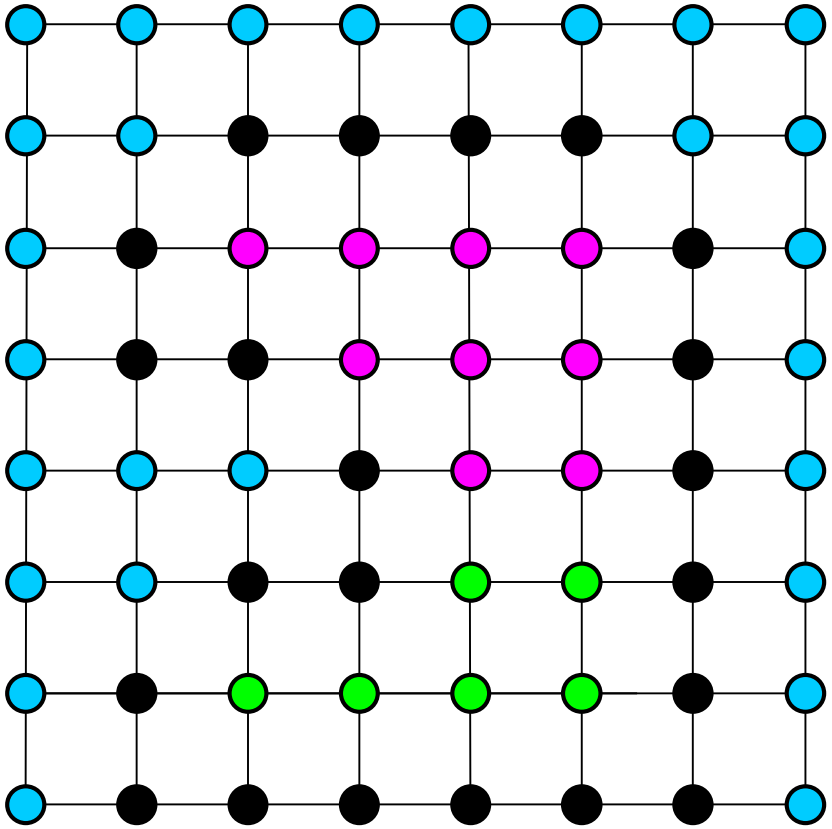


4-connected

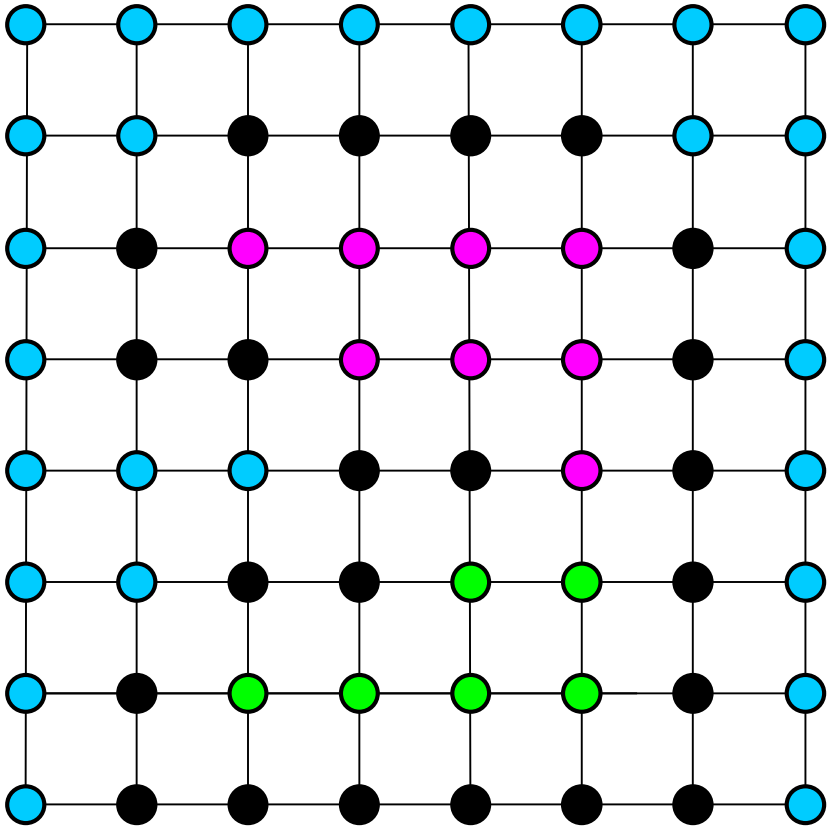


8-connected

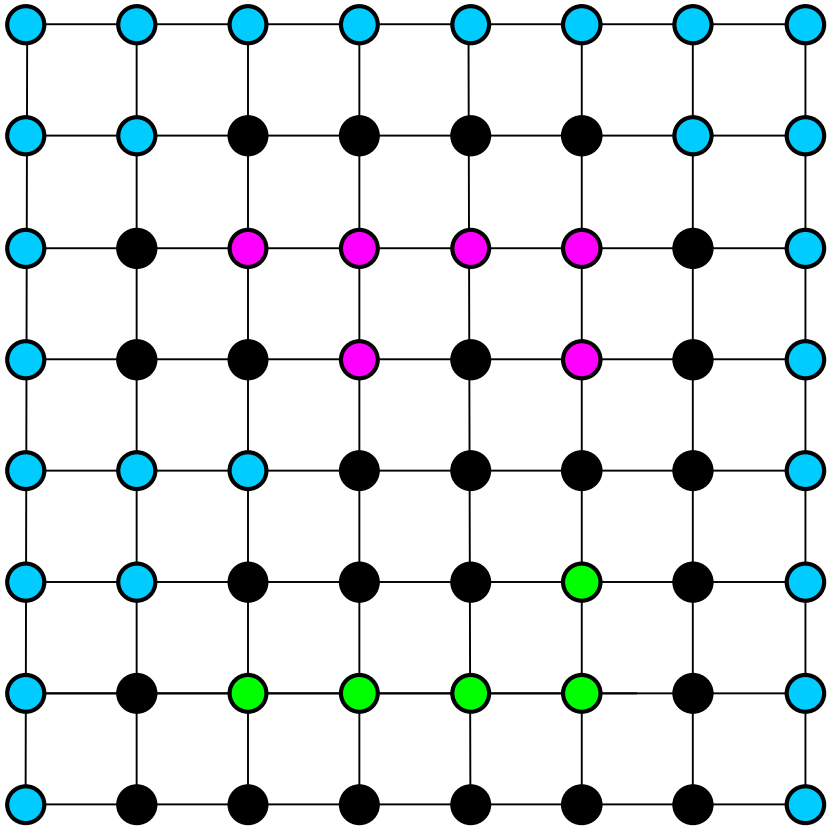
Boundary Fill – Example



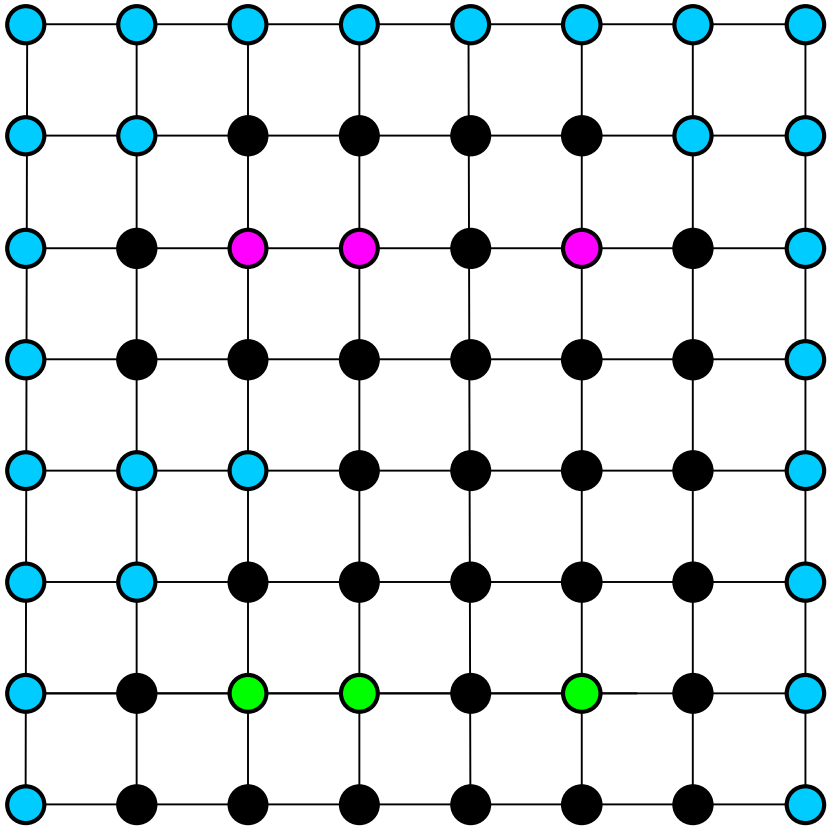
Boundary Fill – Example



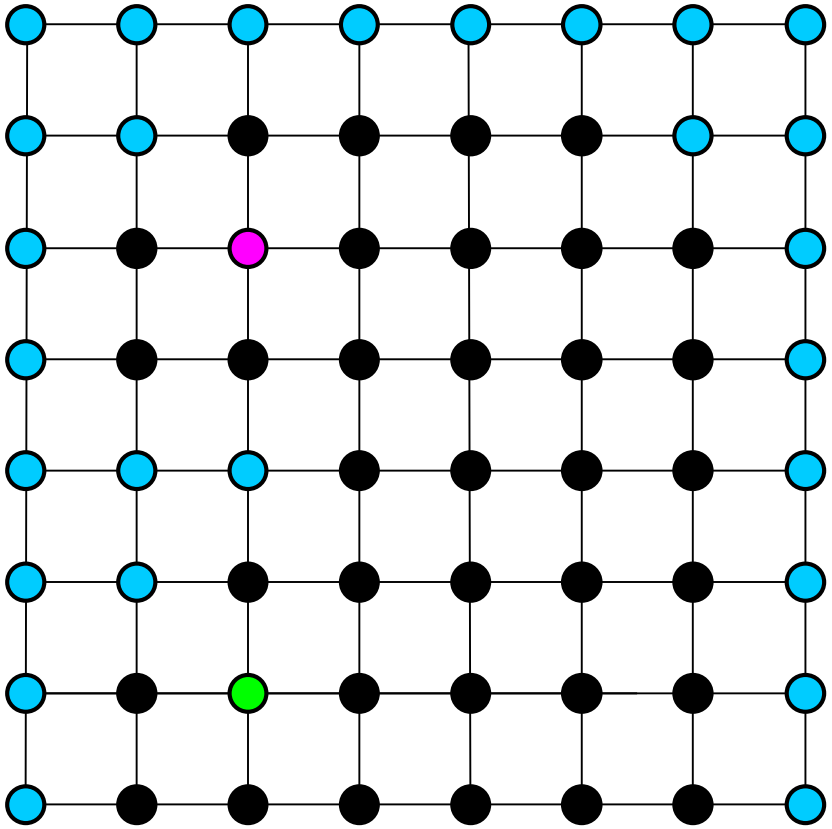
Boundary Fill – Example



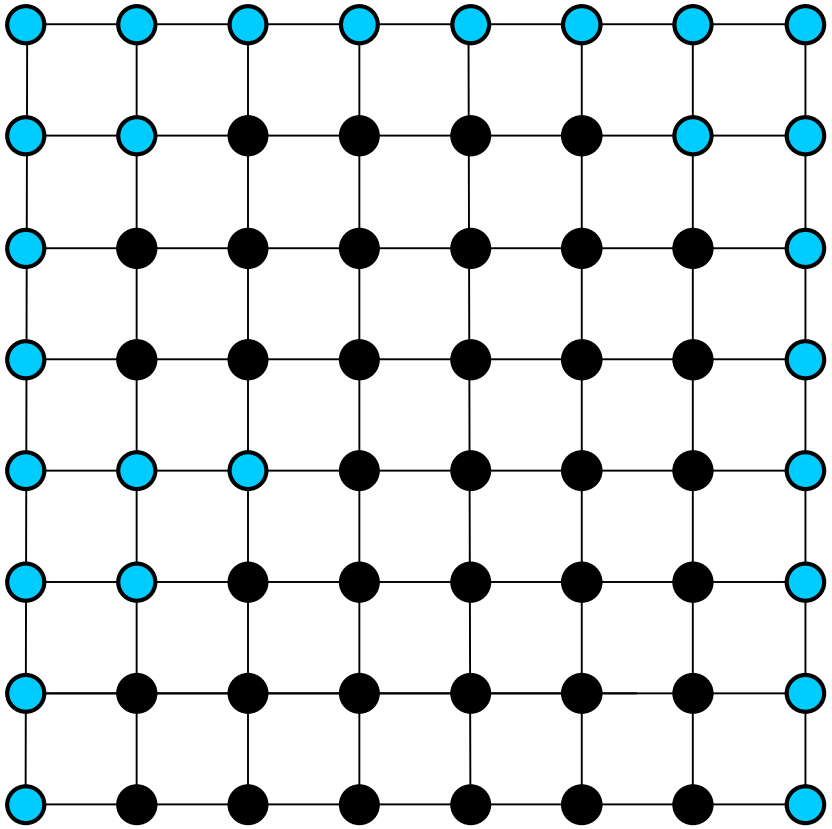
Boundary Fill – Example



Boundary Fill – Example



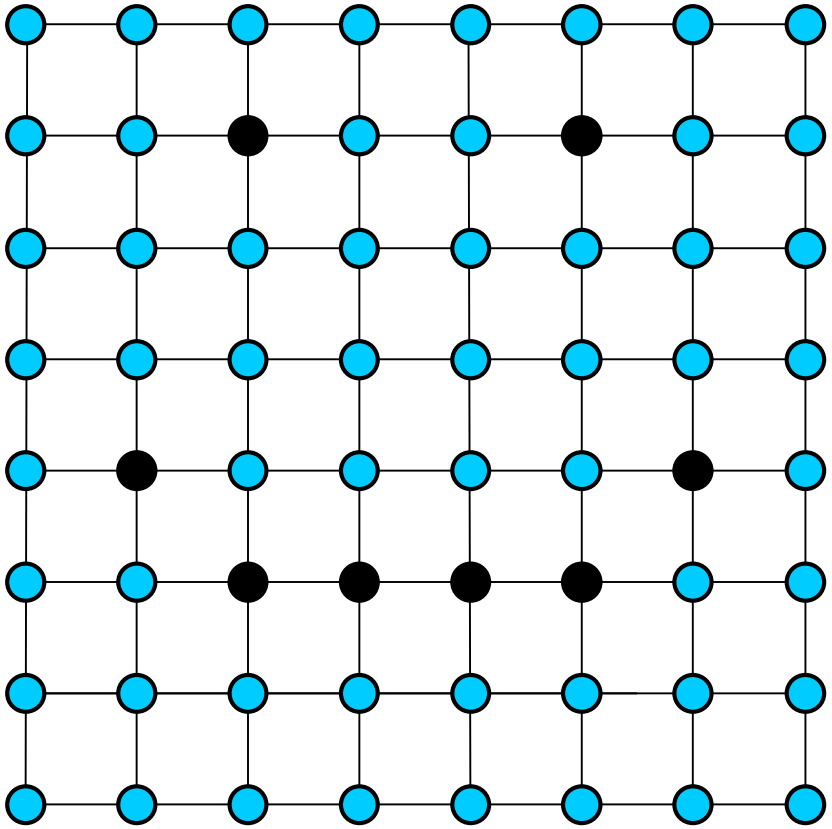
Boundary Fill – Example



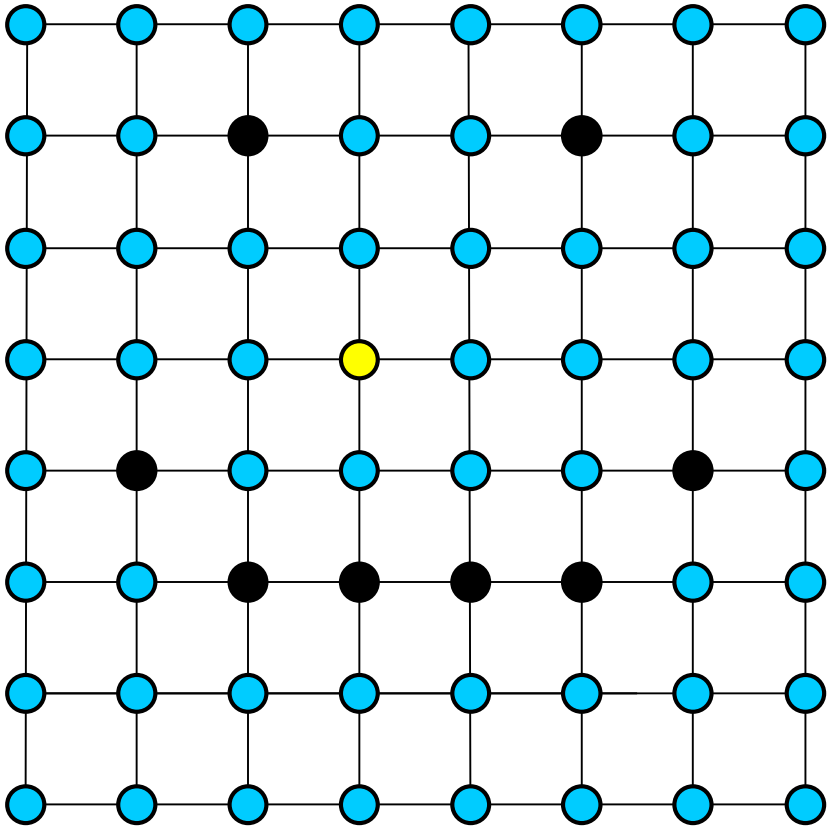
Flood Fill

- Start with a point
- Define color under that point as the interior color
- Recursively recolor outward from that point
  - If neighbor is interior color, then recolor and recur
- Contiguous regions of the same color are recolored

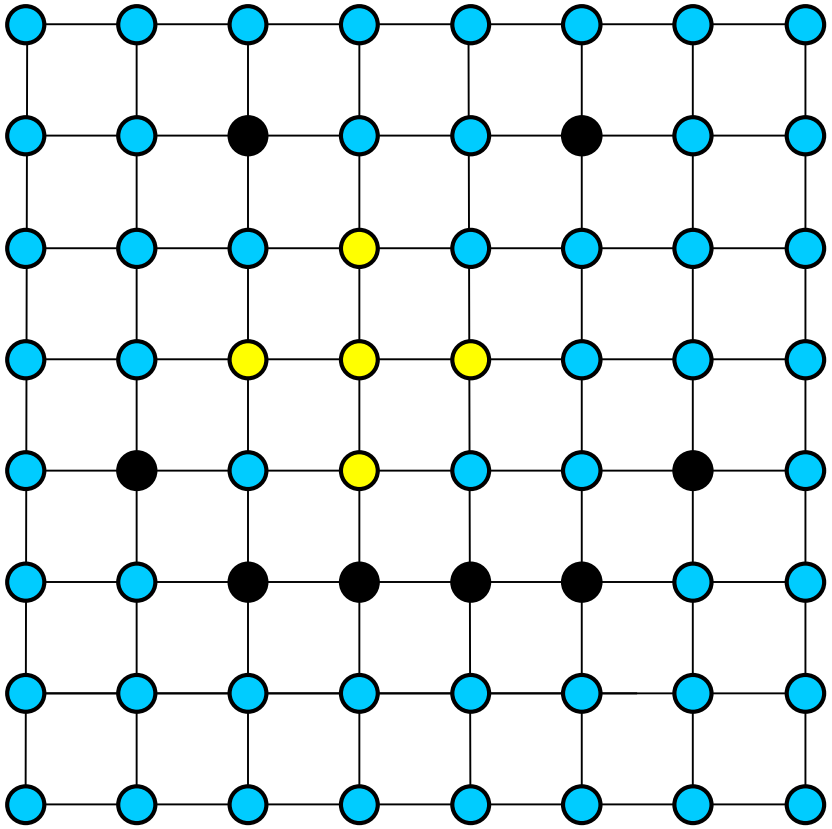
Flood Fill – Example



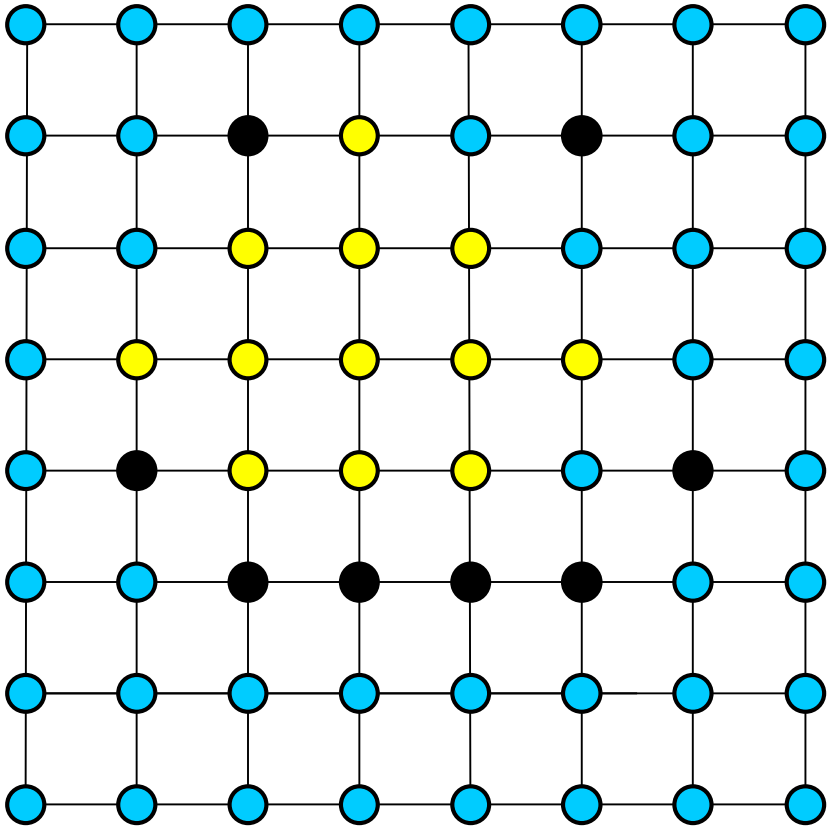
Flood Fill – Example



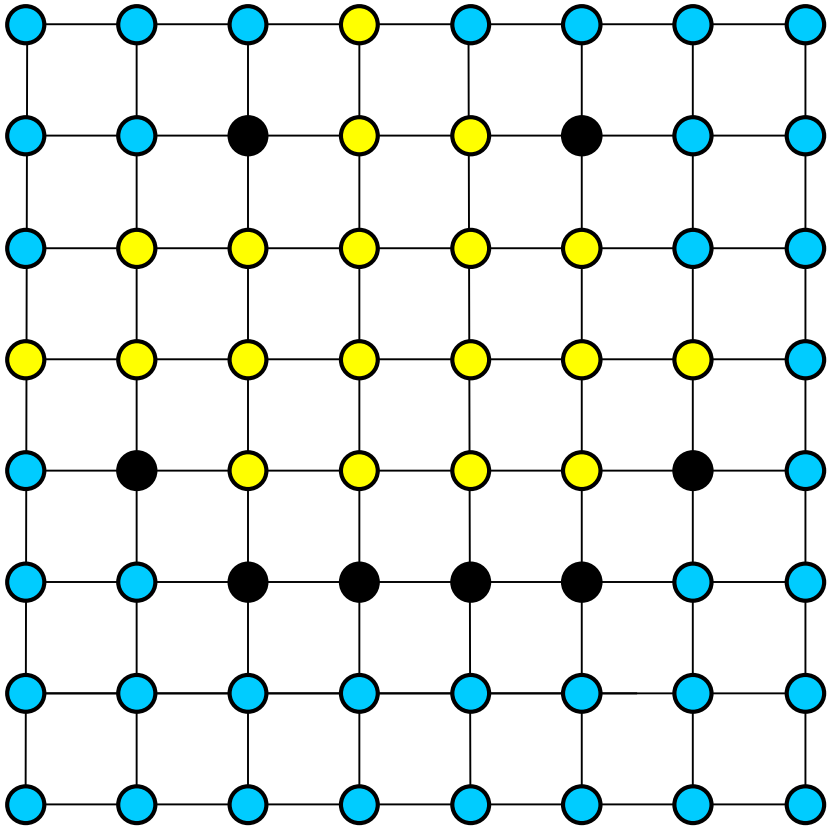
Flood Fill – Example



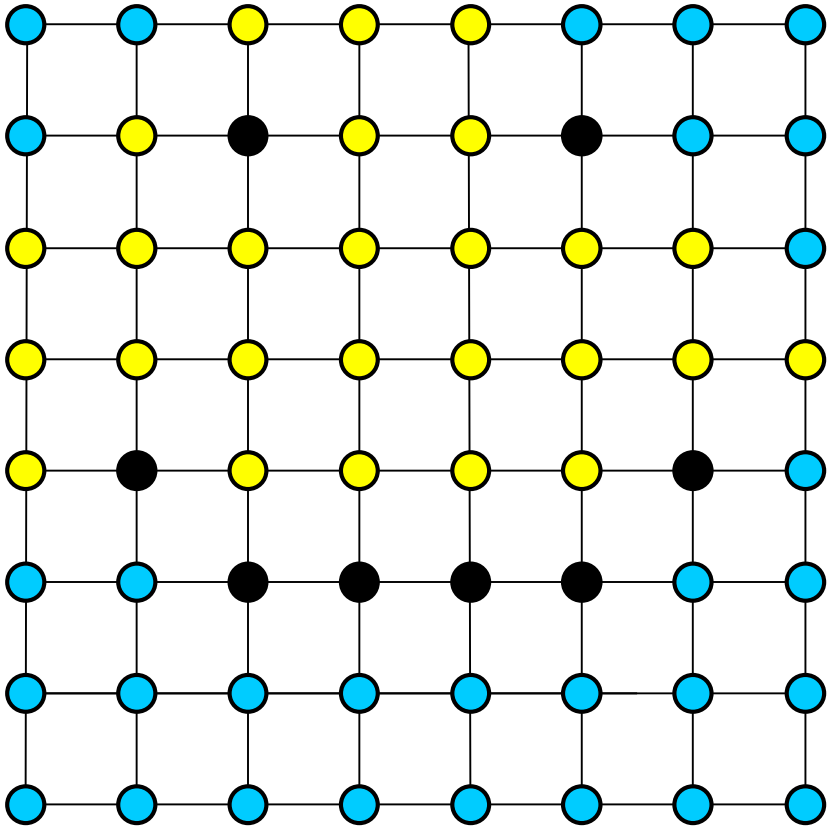
Flood Fill – Example



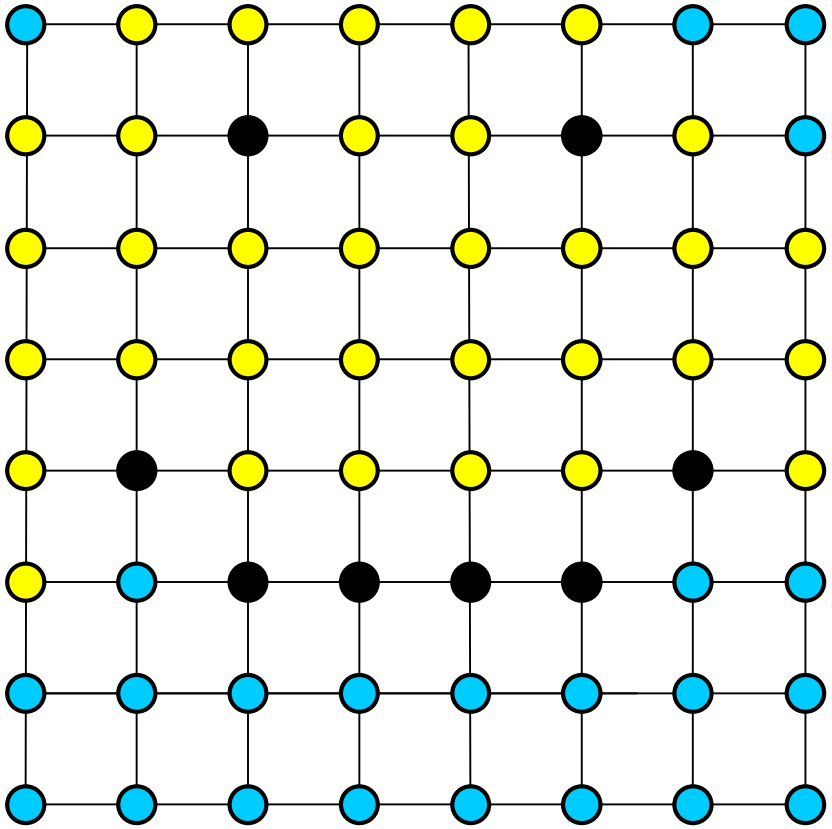
Flood Fill – Example



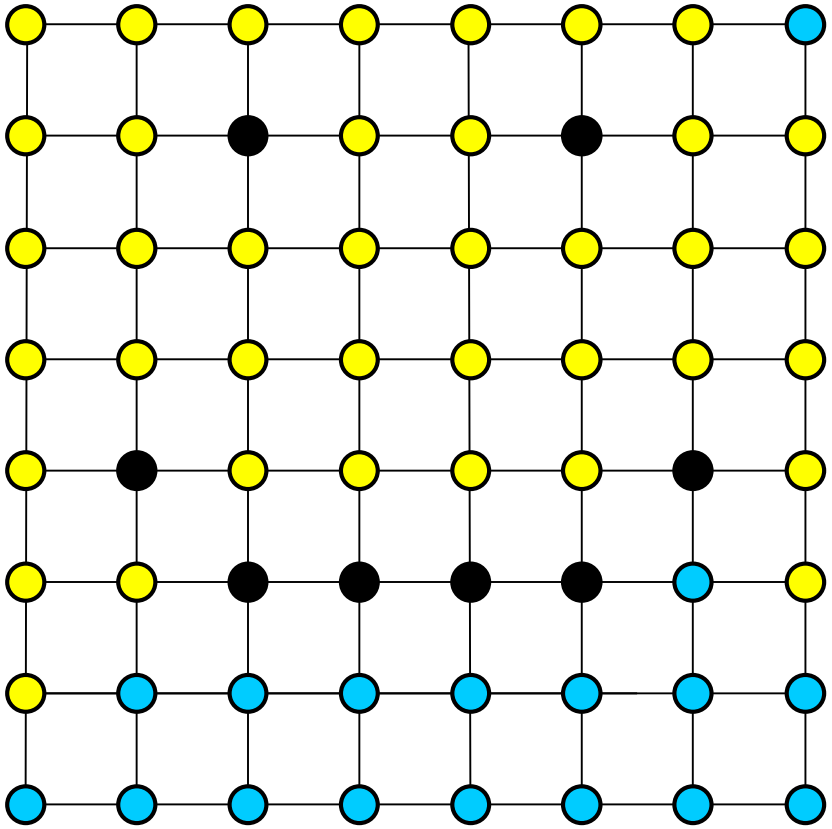
Flood Fill – Example



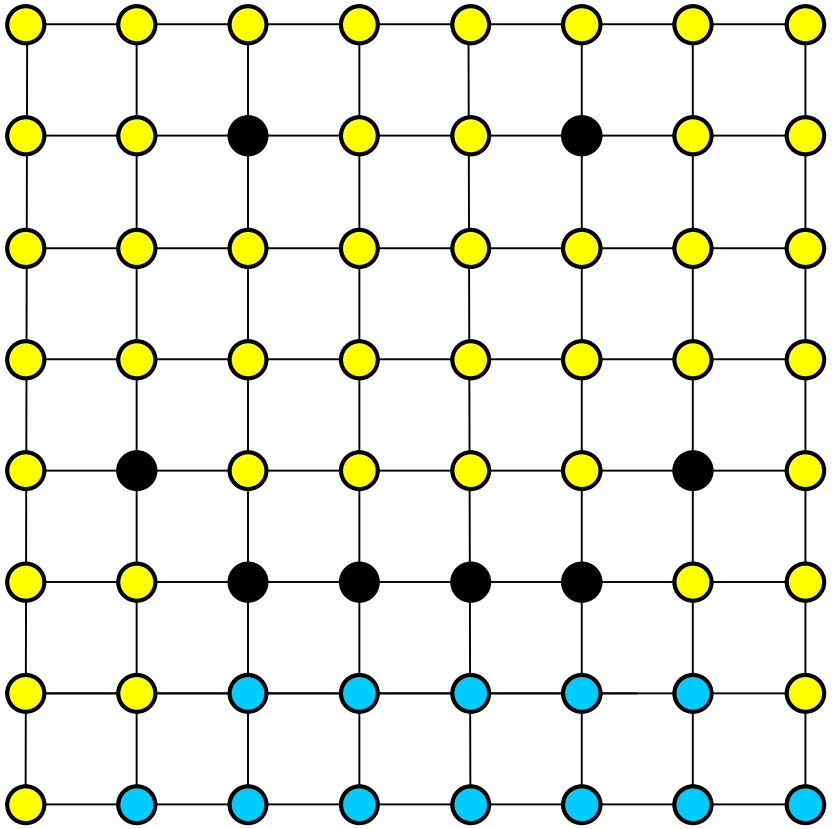
Flood Fill – Example



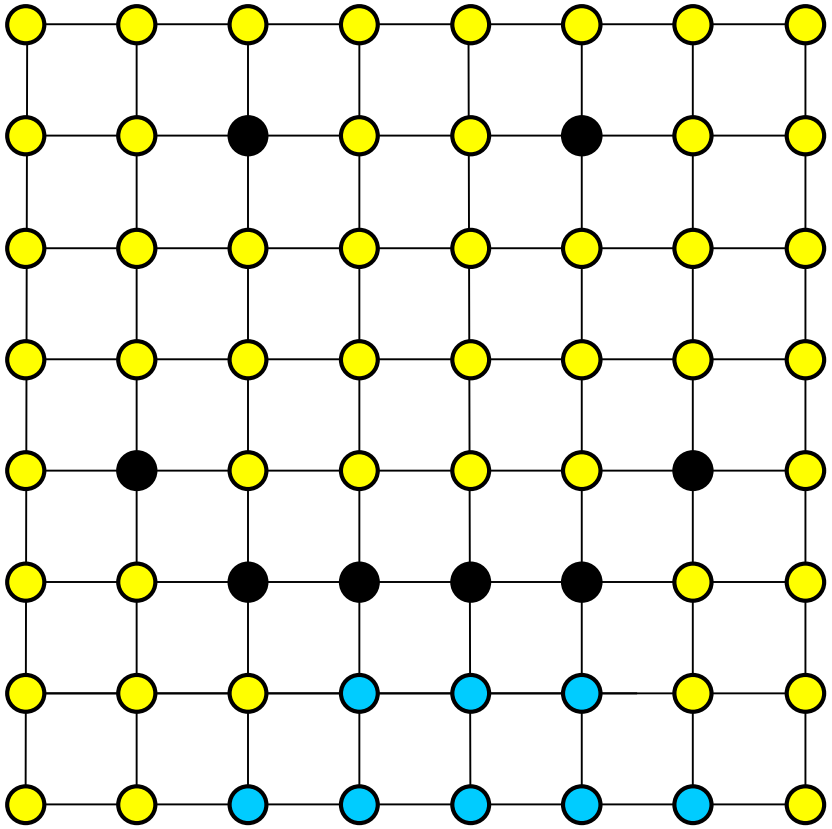
Flood Fill – Example



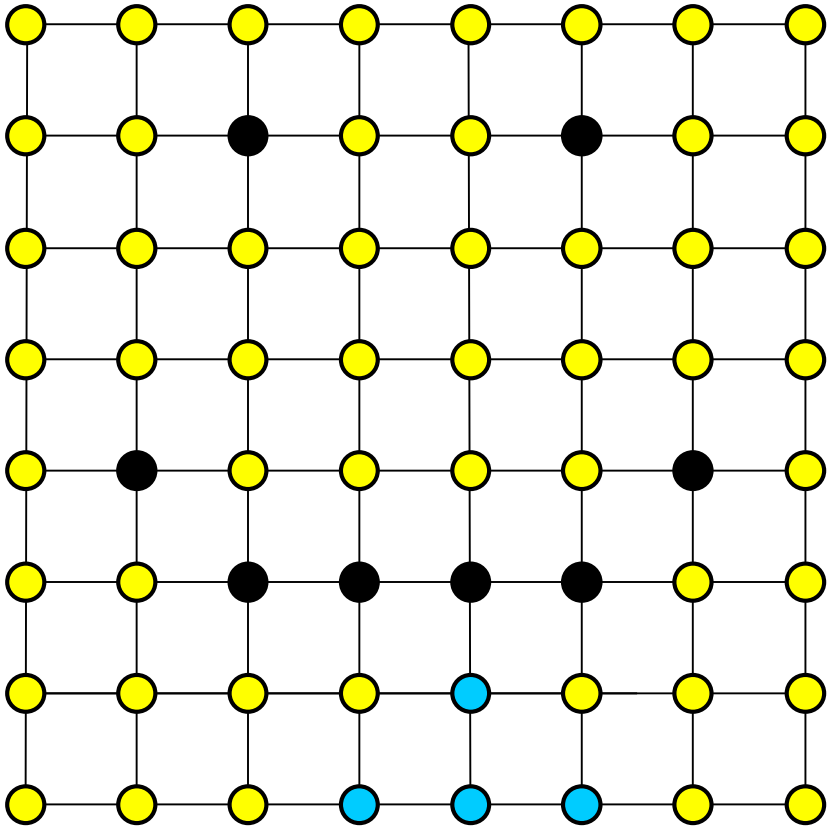
Flood Fill – Example



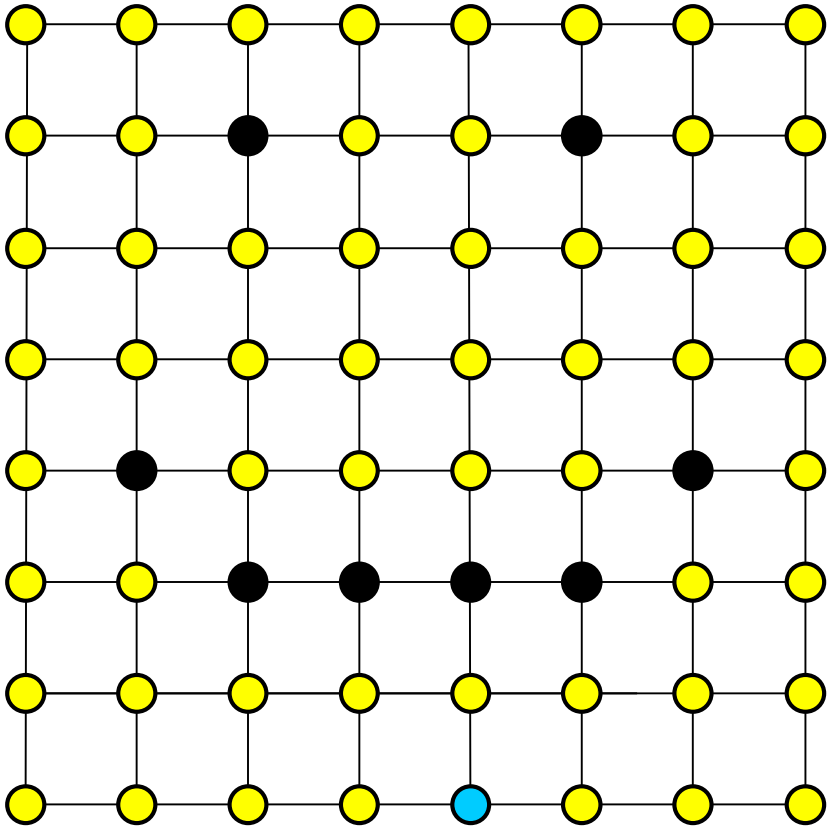
Flood Fill – Example



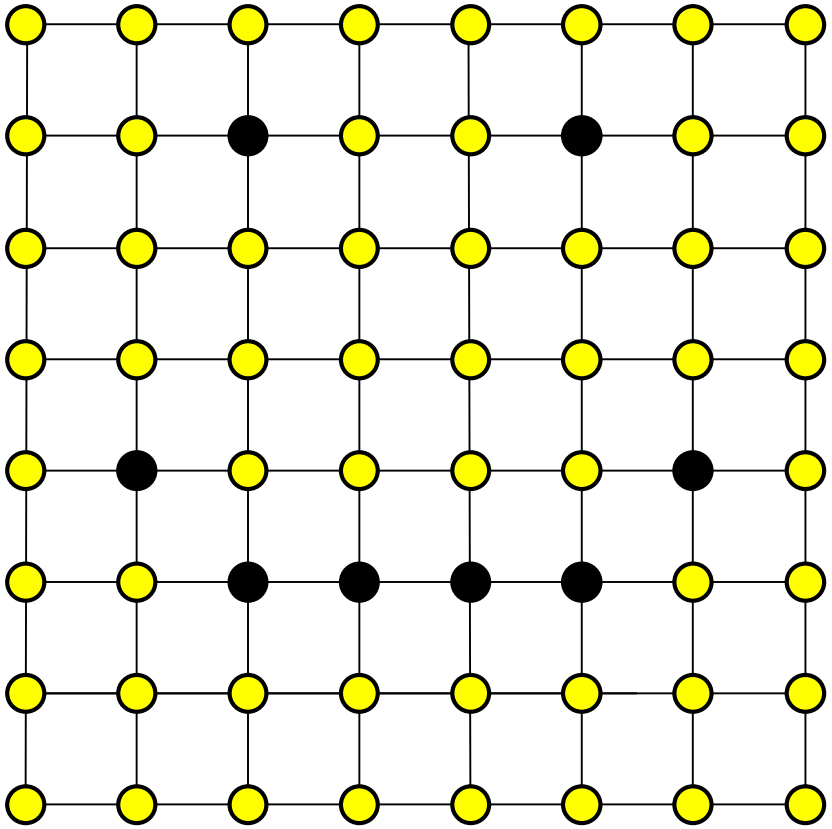
Flood Fill – Example



Flood Fill – Example

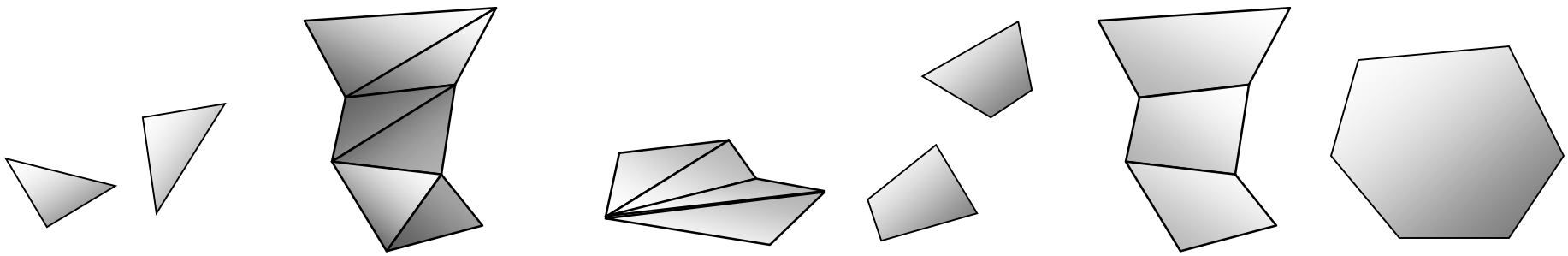


Flood Fill – Example

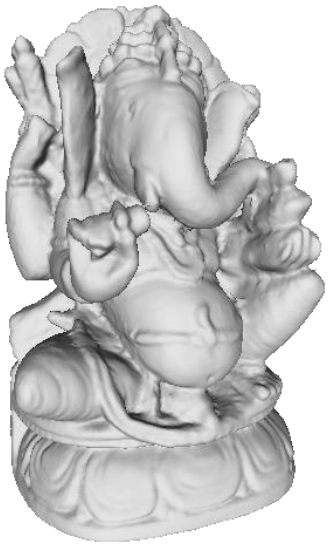


OpenGL: Drawing Polygons

- Lots of different primitives supported
- GPU only draws triangles
  - OpenGL triangulates all polygons
  - Problems with concave polygons!
- How data is passed to GPU makes a significant difference in speed



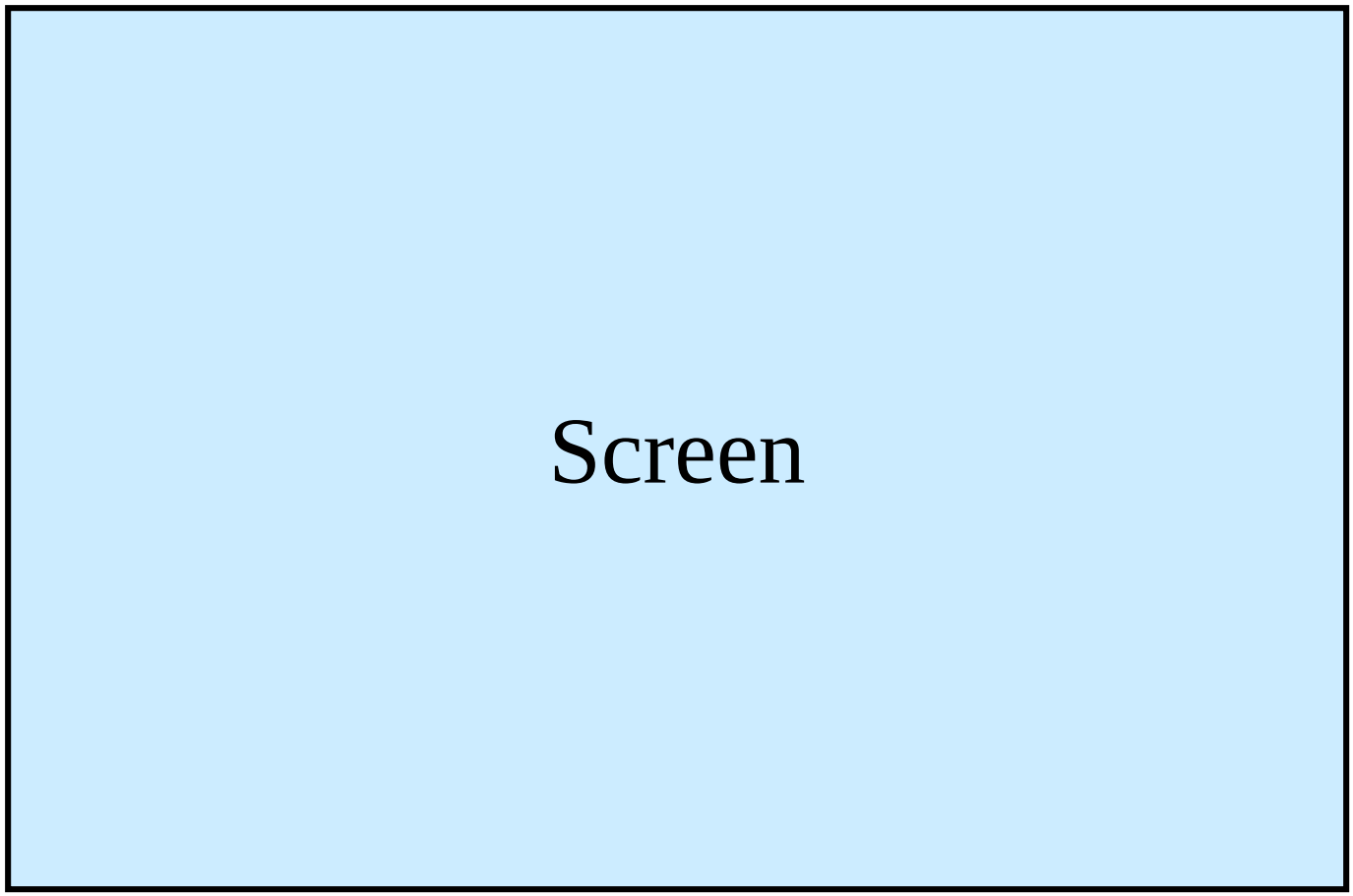
Performance



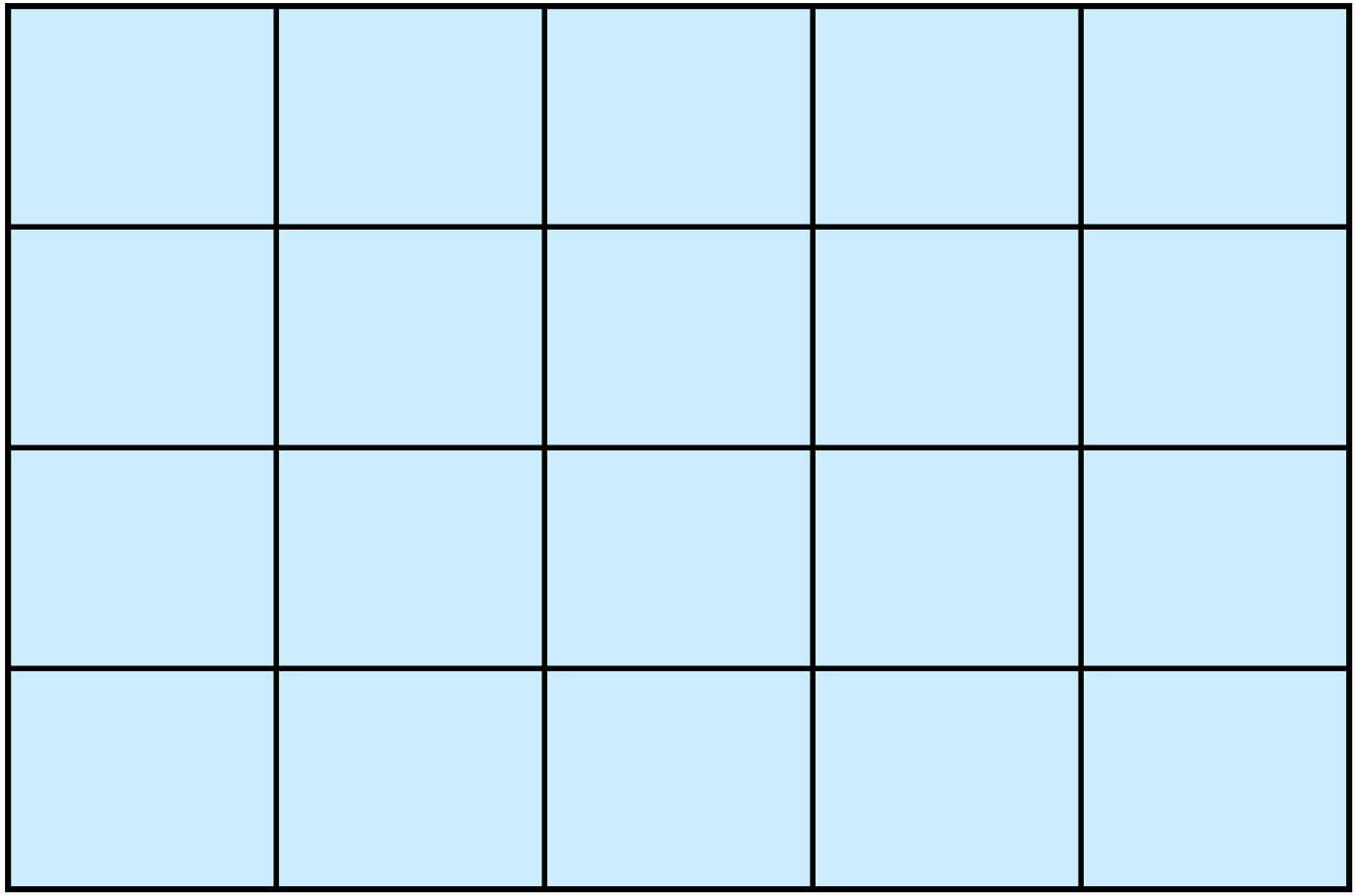
	Nvidia 7300 GT[1]	Nvidia 8800 GTX[1]	ATI Radeon HD 4850[2]	ATI Radeon HD 4850[2] New Drivers
Immediate Mode	15.5	15.5	21.0	33.0
Display Lists	28.3	22.0	463.5	497.5
Vertex Arrays	33.5	35.5	75.0	335.0
Vertex Buffer Objects	50.0	200.0	476.3	506.0

Frames per second displaying a 413,236 triangle model. CPU was an Intel Core 2 6700[1] or Core i7 940[2].

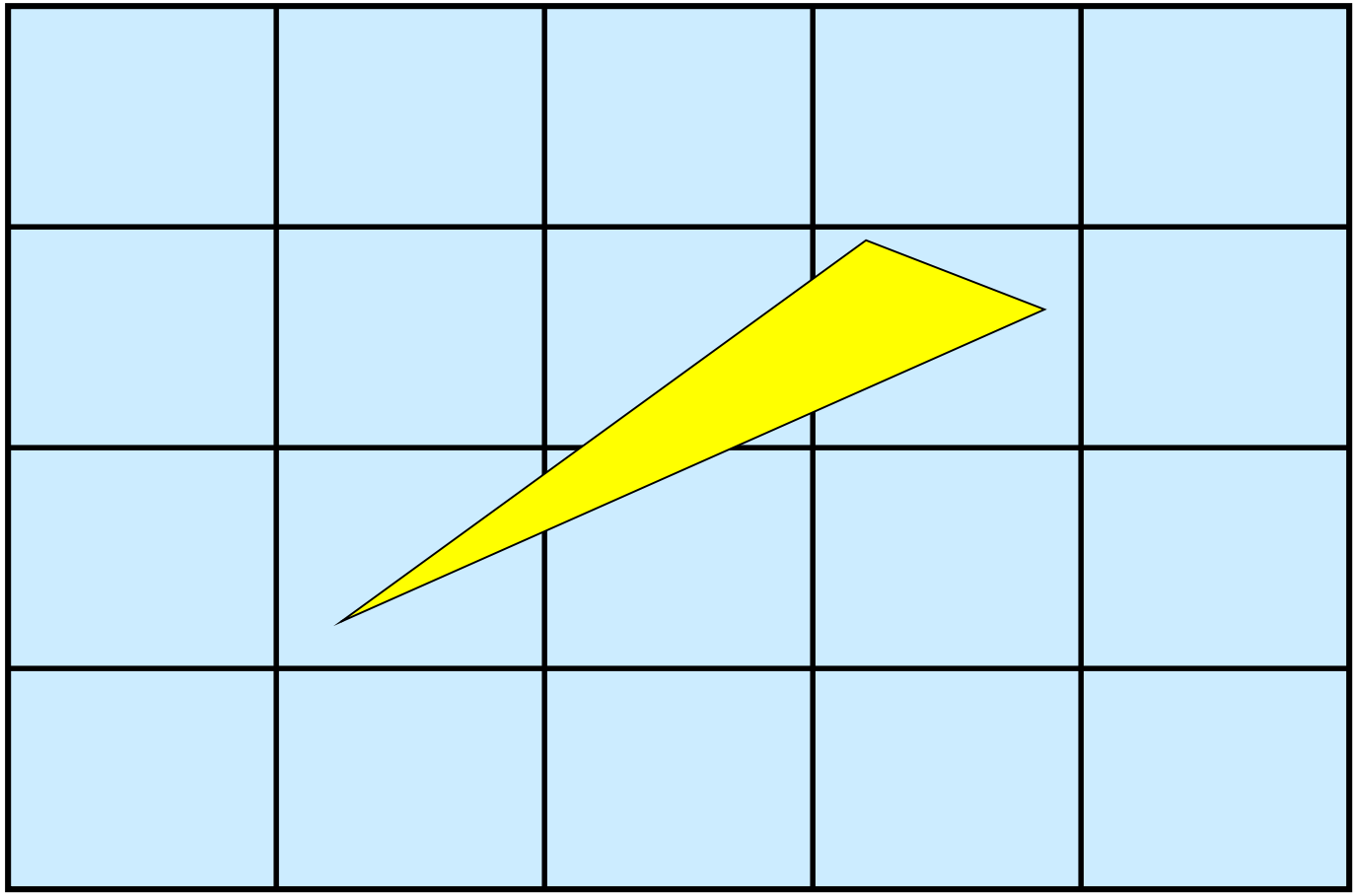
Tile-Based Rasterization



Tile-Based Rasterization



Tile-Based Rasterization



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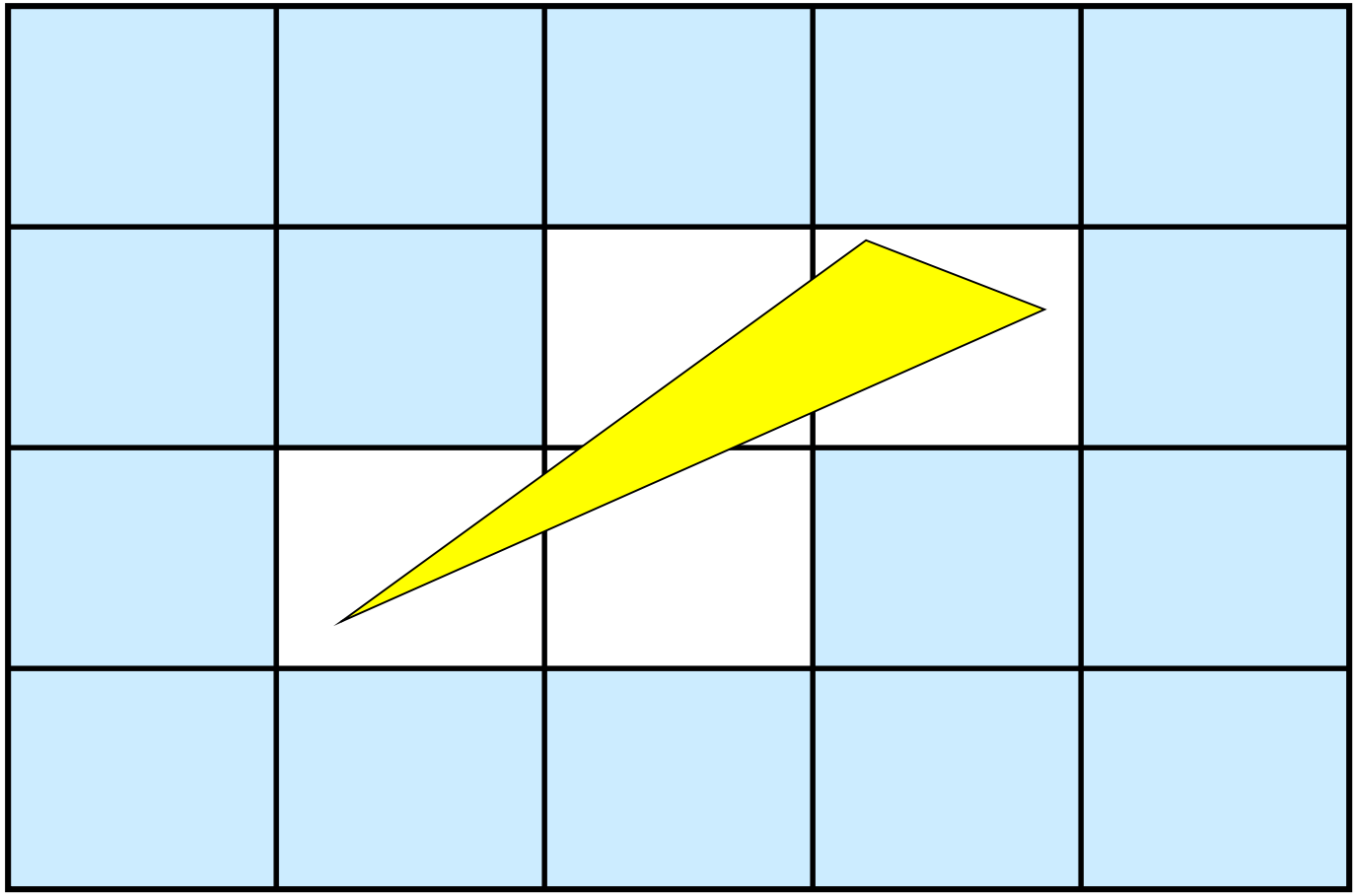

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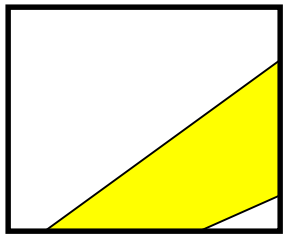
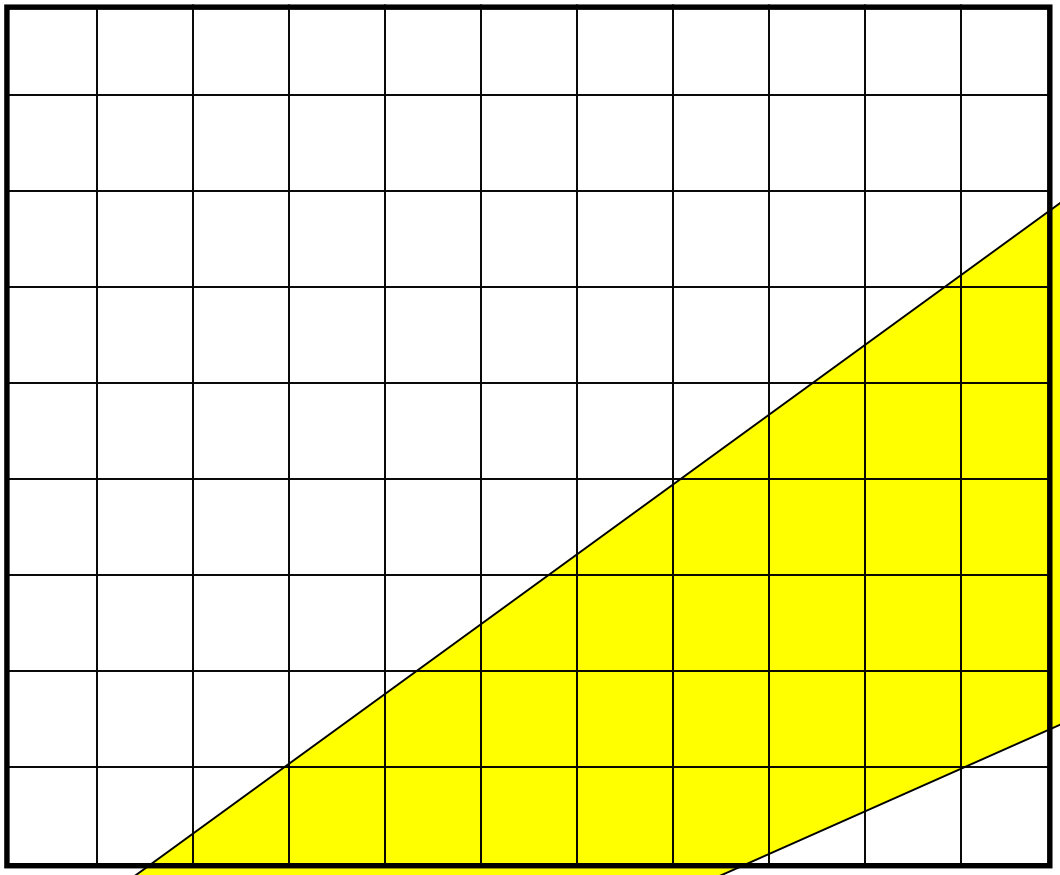
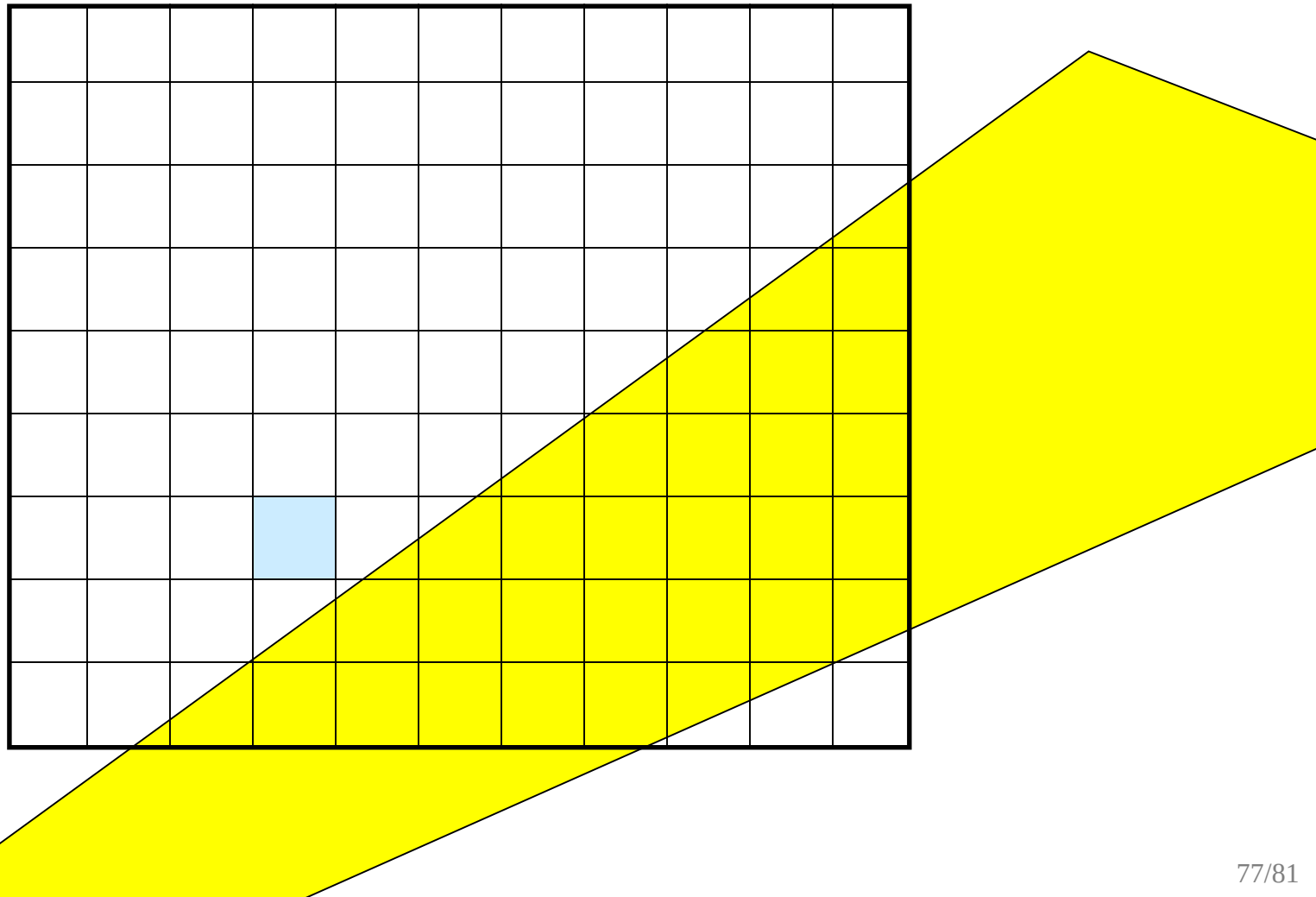


- Each thread draws polygon into local frame buffer
- Copies local frame buffer into global frame buffer when complete

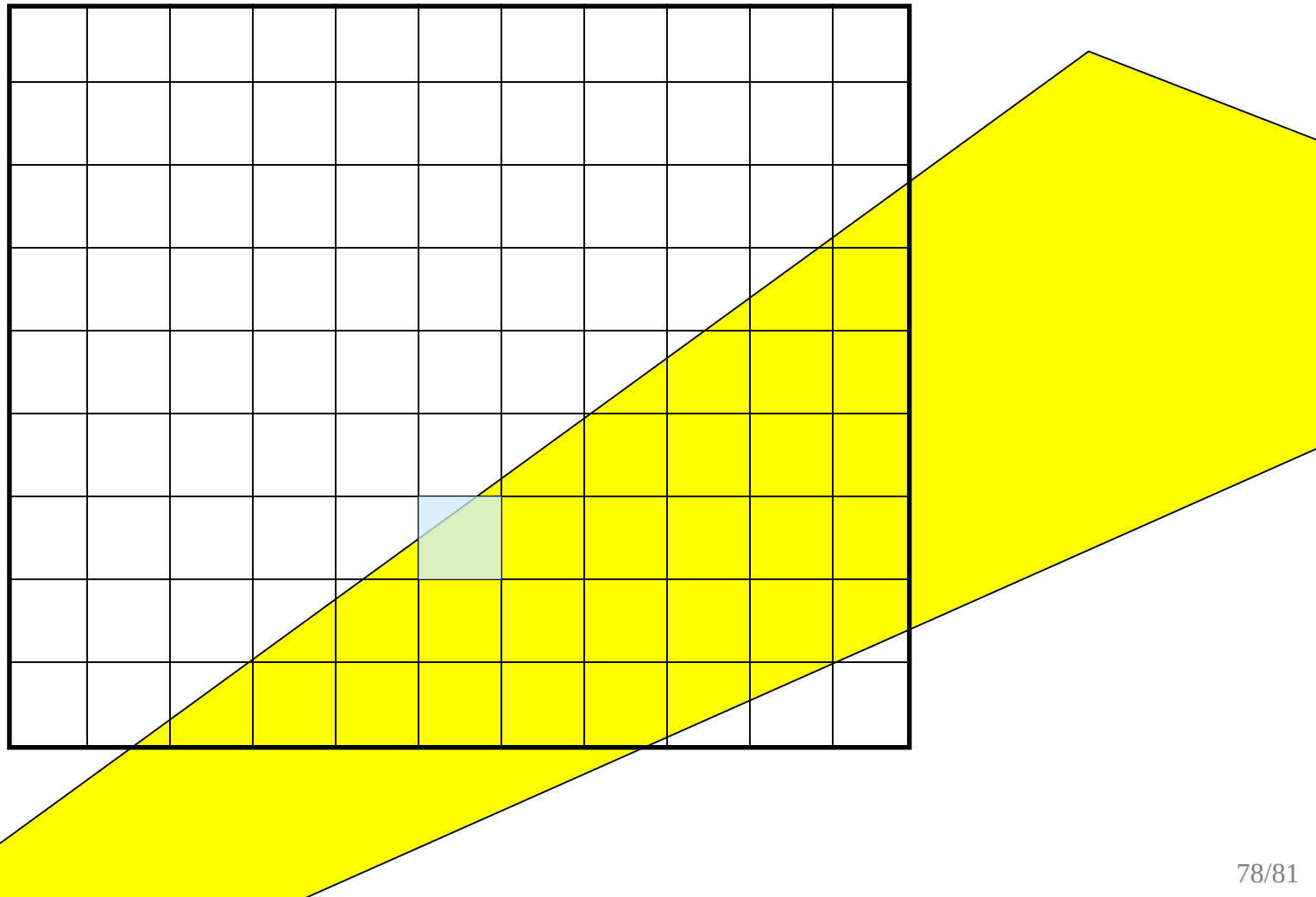
Even More Parallelization



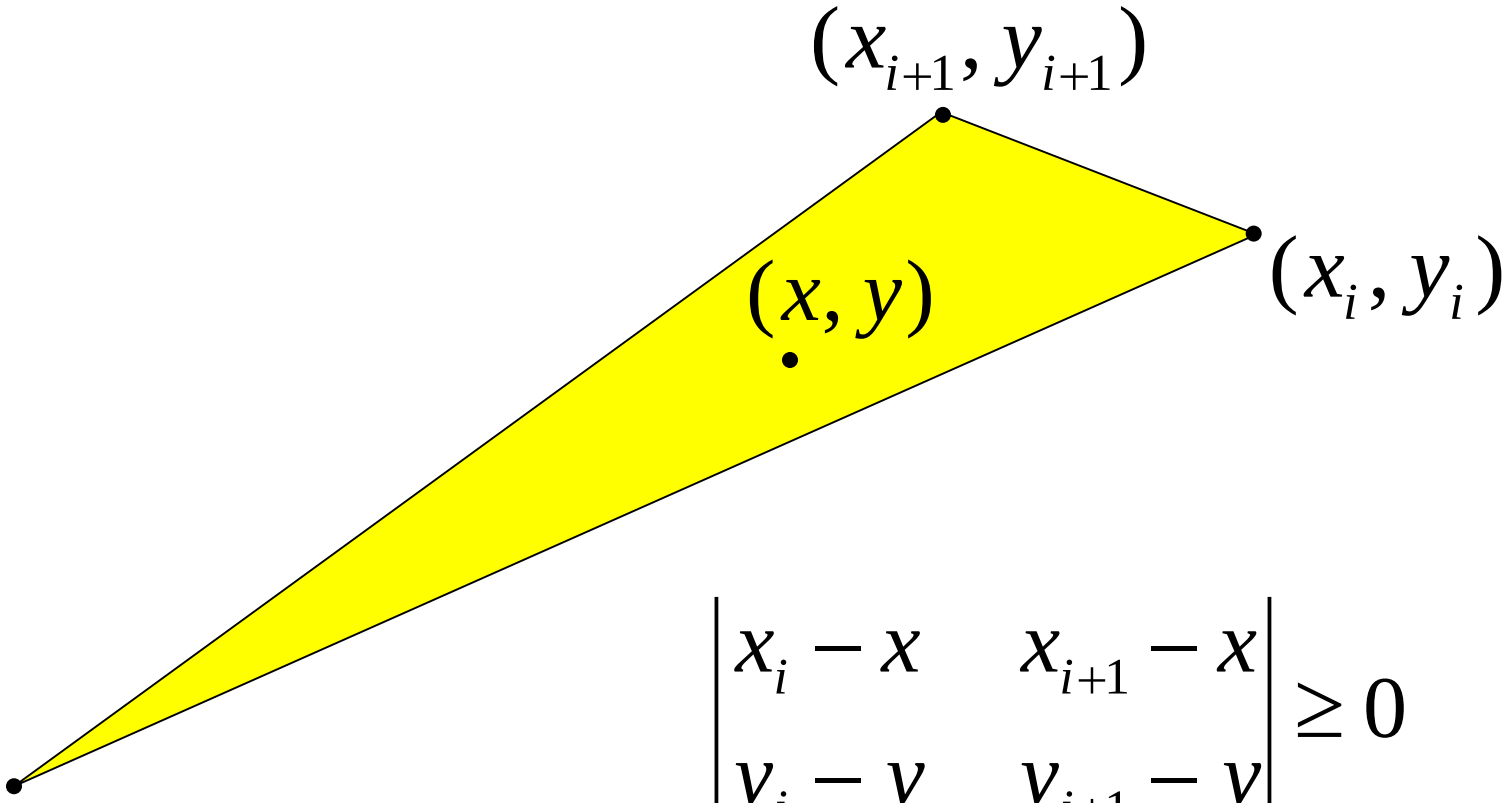
Even More Parallelization



Even More Parallelization

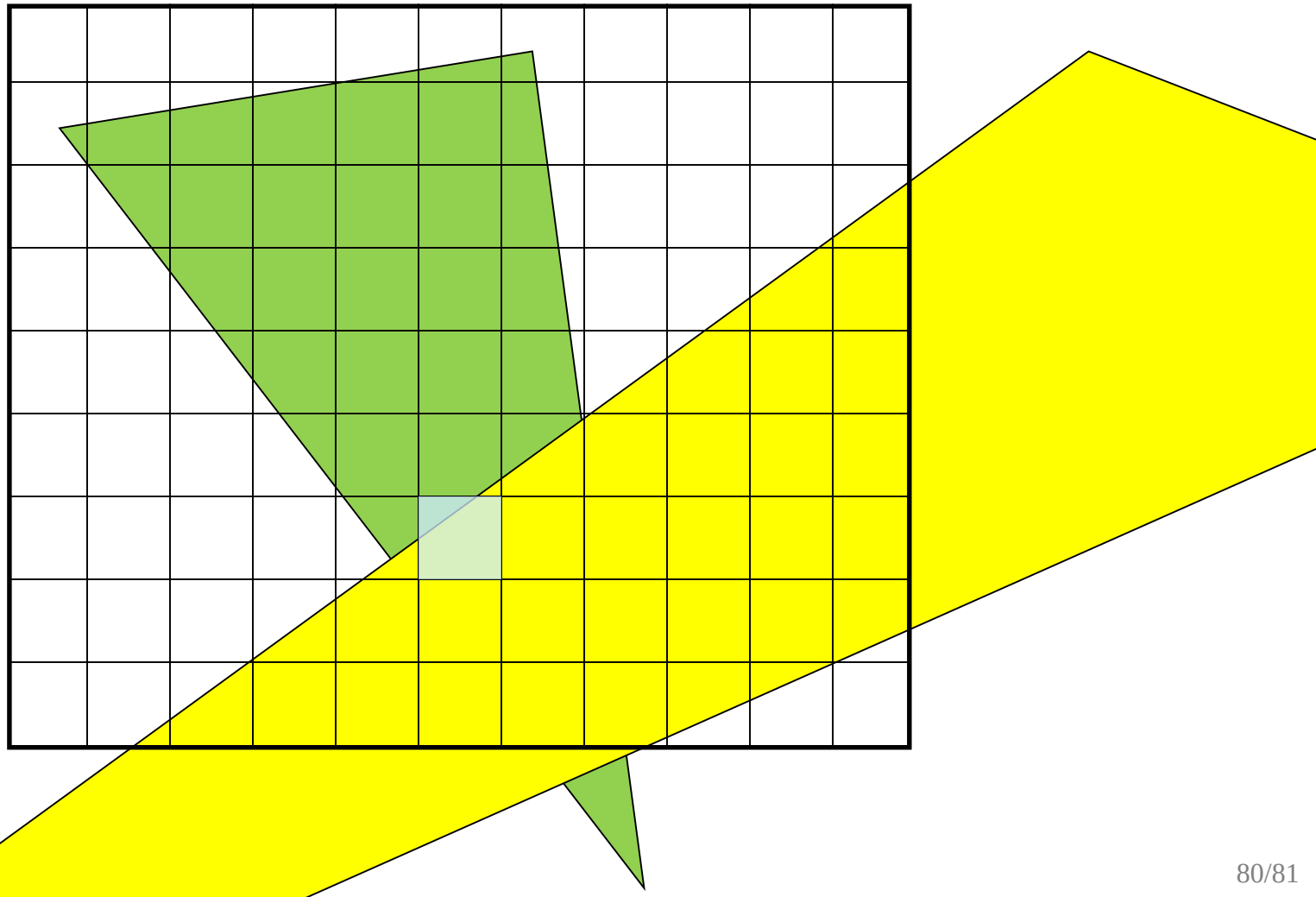


Point in Triangle



$$\begin{vmatrix} x_i - x & x_{i+1} - x \\ y_i - y & y_{i+1} - y \end{vmatrix} \geq 0$$

Even More Parallelization



Even More Parallelization

Only need to check until first polygon hit