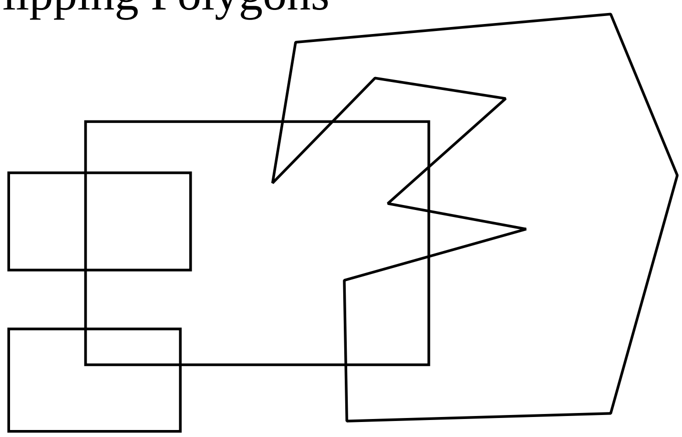
# 2D Graphics Primitives IV

Clipping polygons

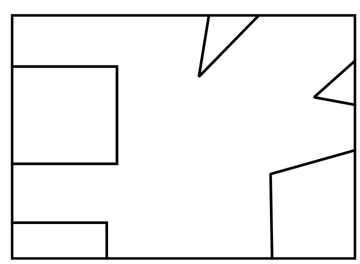
Antialiasing

## Clipping Polygons

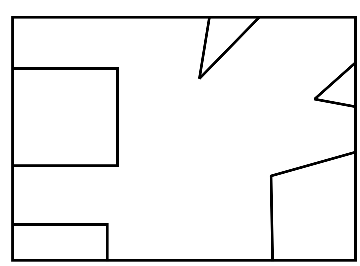


Original Scene and Clipbox

If just clip lines



Want to clip polygons

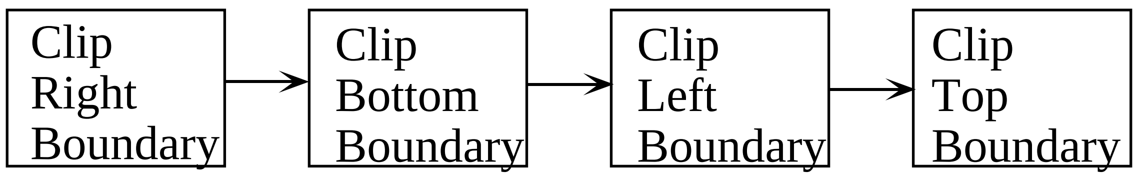


# Sutherland-Hodgeman Polygon Clipper

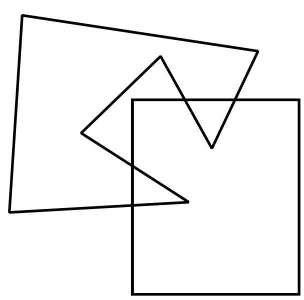
Divide and conquer algorithm

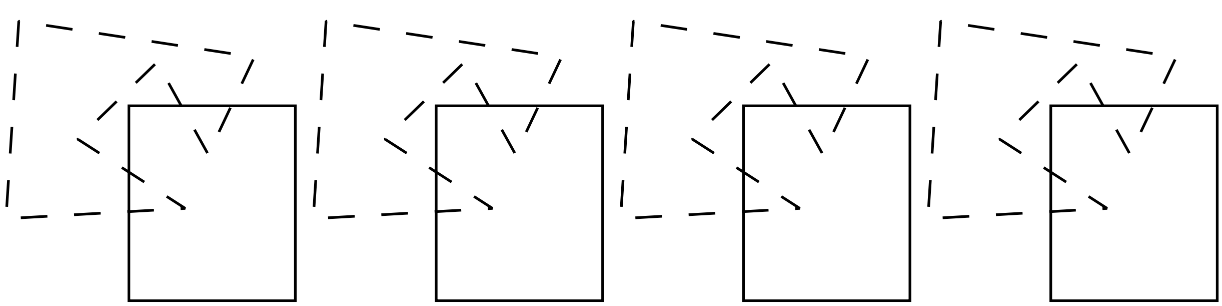
Clipping against clip-region
Clip against each region edge

Parallel implementation
Pipeline implementation



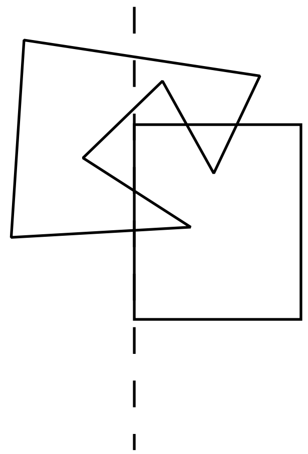

Input a list of points (vertices)
Each stage of pipeline outputs an updated list of vertices





Can generalize to any convex polygon clip region

How Clip Polygon by a Boundary?



Need concept of inside and outside of boundary

Consider a polygon described by a sequence of vertices

$V = (v_1, v_2, v_3, \dots , v_n)$

Want to clip against clip-region to get clipped polygon

$C = (c_1, c_2, c_3, \dots , c_m)$

In general will m = n?

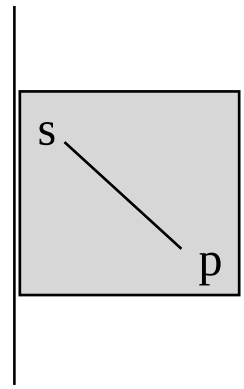
Let E be the edge list of V

$E = \{ sp \mid s = v_i, p = v_{i+1}\} + \{v_n v_1\}$

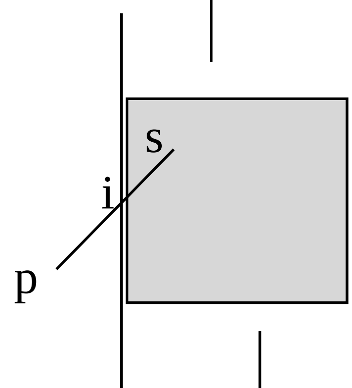
note we need to include last edge

For each edge sp in E

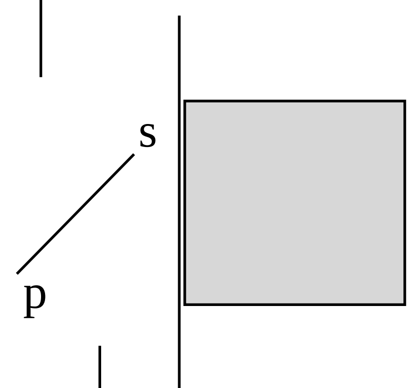
if s and p are both inside boundary,
then output p



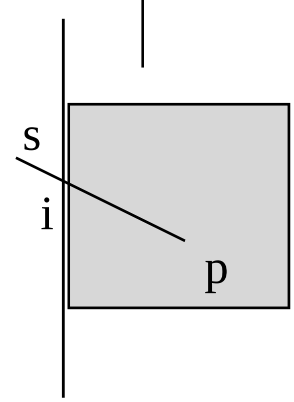

if s is inside and p is outside
then output intersection, i




if s and p both outside,
then output nothing

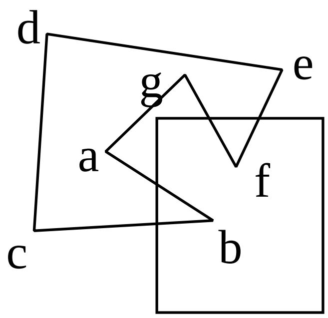



if s is outside and p is inside,
then output i and p




The output list from one boundary is the input list for the next

CDQ: Hand Simulation of Sutherland-Hodgman Polygon Clipping




V = (a, b, c, d, e, f, g)

E = ?

Find the updated E after clipping by:

right boundary

E =

bottom boundary

E =

left boundary

E =

top boundary

E =

Is this the desired output for this polygon?

# Weiler-Atherton Polygon Clipping

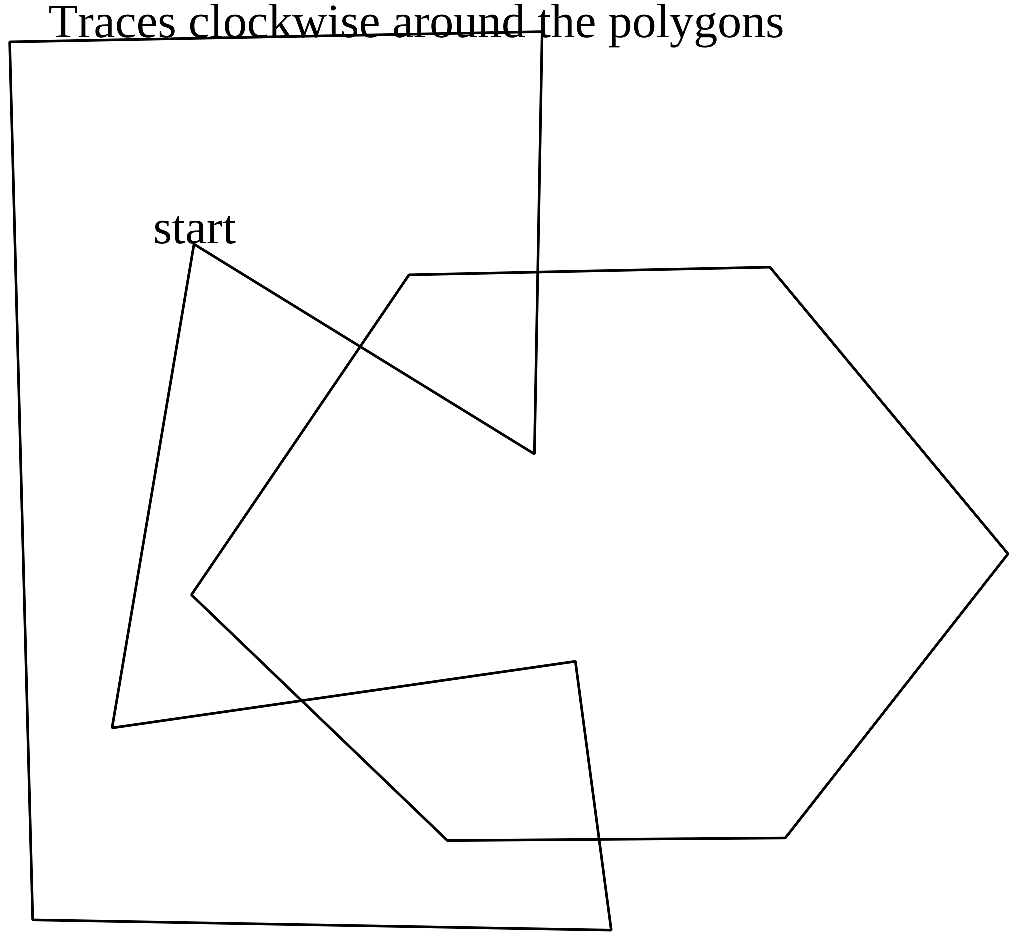
Solves problem just encountered

Very general
- Can clip convex polygon by a convex polygon
- Can clip a concave polygon by a convex polygon

Clip region is called the clip polygon

Polygon to be clipped is called the subject polygon

Traces clockwise around the polygons



## Algorithm

```
position = start
save = off
trace subject (position)
        if hit clip
                if (entering clip and subject not saved)
                        save = on
                        trace subject(current)
               else if (leaving clip and clip right not saved))
                        save = on
                        push current onto stack
                        trace clip(current)
                else
                        save = off
                        if stack empty
                                end
                        else
                                popstack (current)
                                trace subject (current)
end

trace clip (position)
        if hit subject
                if subject right not saved
                        turn on save
                        trace subject (current)
                else
                        turn off save
                        if stack empty
                                end
                        else
                                popstack (current)
                                trace subject (current)
end
```

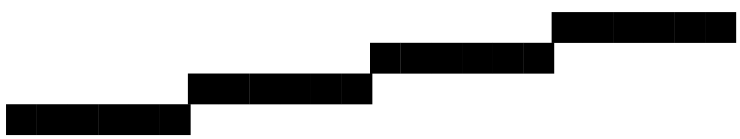
# Antialiasing

Or: "How to overcome the Jaggies"

When scan converting lines (or filled polygons)
get jaggies - small step edges

By product of digitization

Can we improve things by increasing the resolution of the display?



Not exactly
- Does increase the number of distinct orientations we can display
- But still a problem

Can we overcome this problem with binary displays?

How to overcome the problem with grey-scale displays

# Method 1: Prefiltering

When scan converting an object, compute the value for each pixel that will diminish the perceived aliasing

Pitteway and Watkinson came up with a modification to Bresenham's line drawing algorithm which does the calculations whilst scan converting

Difficult to compute this for nonstraight lines.

Two main approaches:

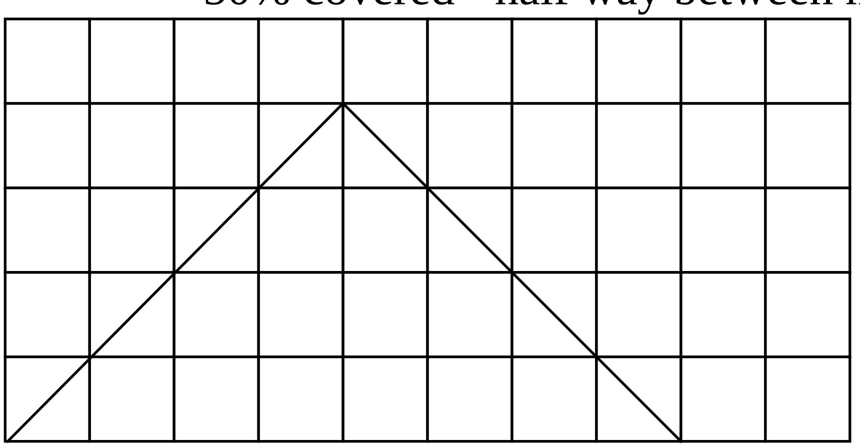
Unweighted Area Sampling

Weighted Area Sampling

Unweighted Area Sampling:

Determine what percentage of a pixel's area is covered by the object

Value of pixel is linear function of this percentage
- Totally covered - max value (foreground color)
- Totally uncovered - min value (background color)
- 50% covered - half way between max amd min



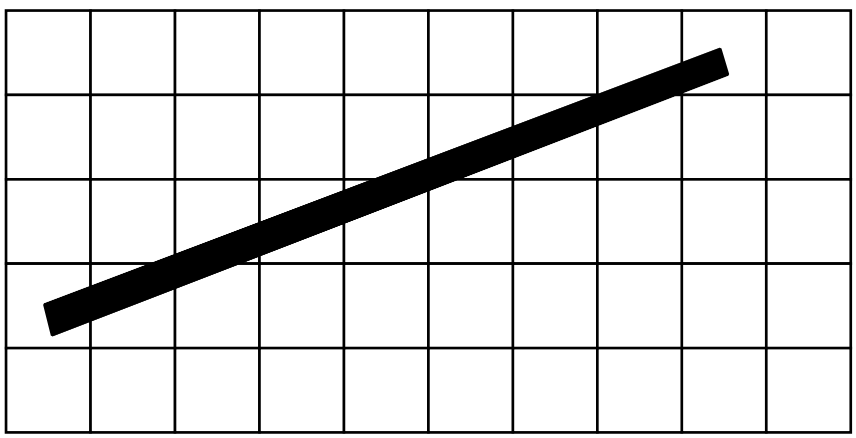
Triangle color: 10
Background: 0

What value for each pixel?

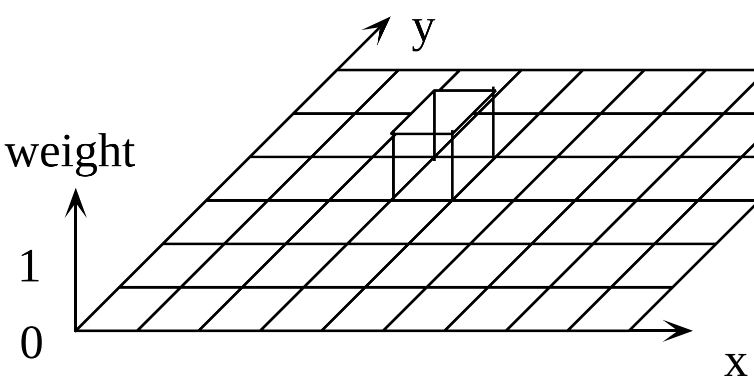
# Weighted Area Sampling

If line passes through middle of pixel, may want to weight it more than if it passes by pixel edge

(Assume now that pixels are square tiles tesselating (tiling) a surface)



Use weighted filter function




Box Filter

Convolve scene with filter for each pixel

filter = f(x,y)
scene = g(x,y)

filtered output = area under f(x,y) times g(x,y)

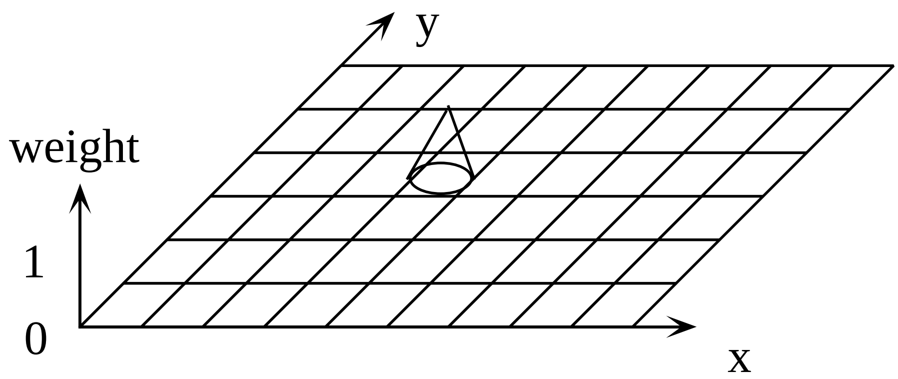
for box filter at pixel i,j

f(x,y) = 1, if i <= x <= i+1, and j <= y <= j+1
= 0, otherwise

Box filter is just the Unweighted Prefiltering

To give more weight at center of pixel
Could use cone shaped filter

May want the base of the cone to be greater than one pixel in diameter




If diameter of cone base (support) = one pixel width for square pixels,
then is all of the scene sampled?

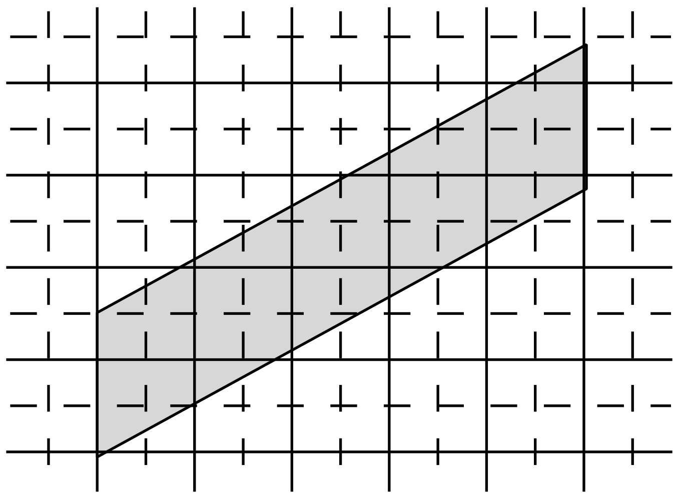
If make support too small, then not all scene is sampled
If make support too large, then may blur scene too much

Support diameter = 2 pixel widths is good compromise

# Method 2: Supersampling

Scan convert a grid that has more pixels than actual display

For each display pixel, compute the average value of the corresponding set of supersampled pixels



Here dashed line intersections are the displayed pixels solid and solid-dashed intersections are supersampled pixels

With this double sampling, average display pixel and it's eight-connected neighbors

(See example)

What is relation between prefiltering and supersampling?

# Method 3: Postfiltering

Just as could use weighted sampling filter in prefiltering, can use weighted sampling filter in postfiltering

Supersample the scene

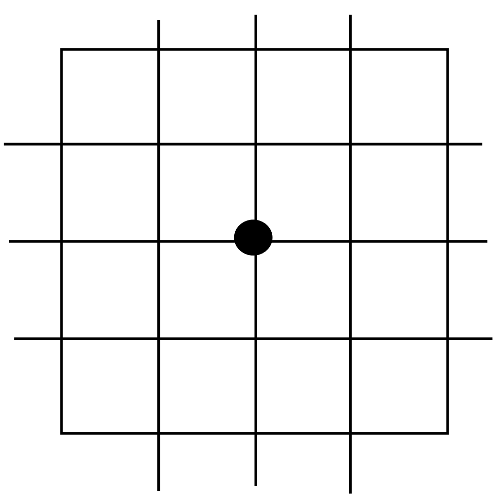
Instead of using straight average, use a weighted average of supersample pixels to compute value of display pixel

If double sample, could use 3x3 filter or even 5x5, 7x7 or greater.

Example filters:

$$\frac{1}{8}\begin{matrix} 0 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 0 \end{matrix} \qquad \frac{1}{16}\begin{matrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{matrix} \qquad \frac{1}{81}\begin{matrix} 1 & 2 & 3 & 2 & 1 \\ 2 & 4 & 6 & 4 & 2 \\ 3 & 6 & 9 & 6 & 3 \\ 2 & 4 & 6 & 4 & 2 \\ 1 & 2 & 3 & 2 & 1 \end{matrix}$$

If quadruple sample, what would be smallest reasonable filter size?



How many extra pixels?

What is effect of using larger filter?