Module 2 - Output Primitives
Topic: Aliasing and Anti-Aliasing

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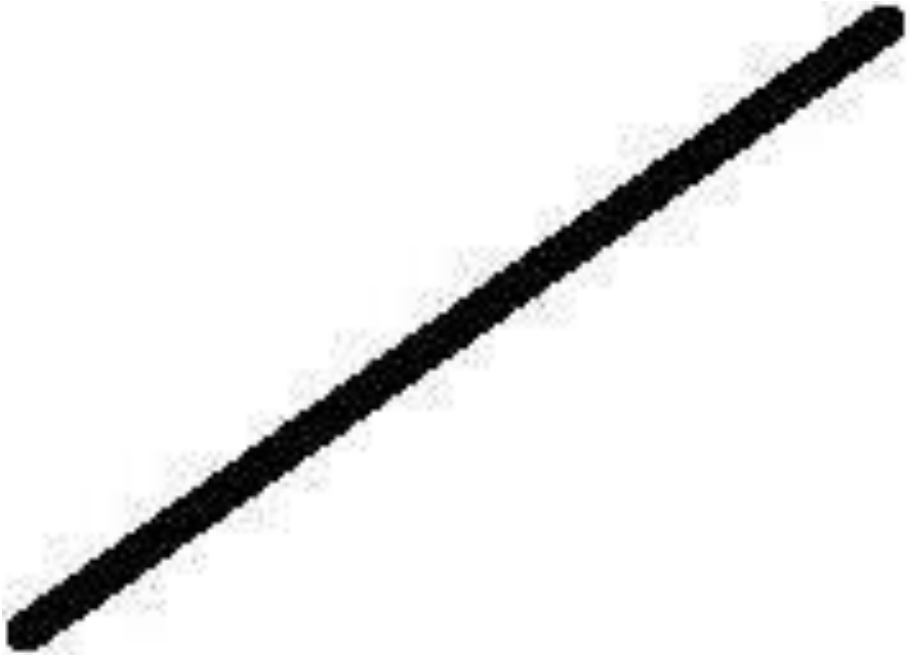
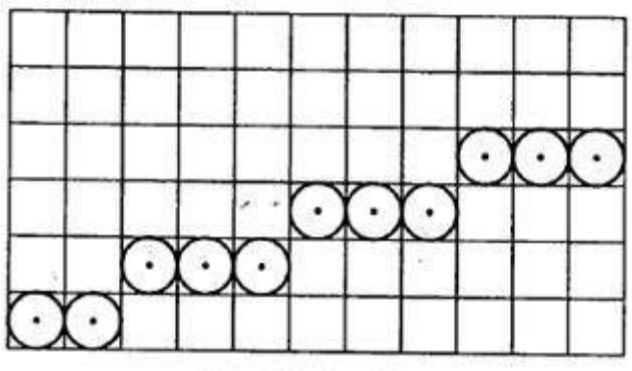
Jagged Line



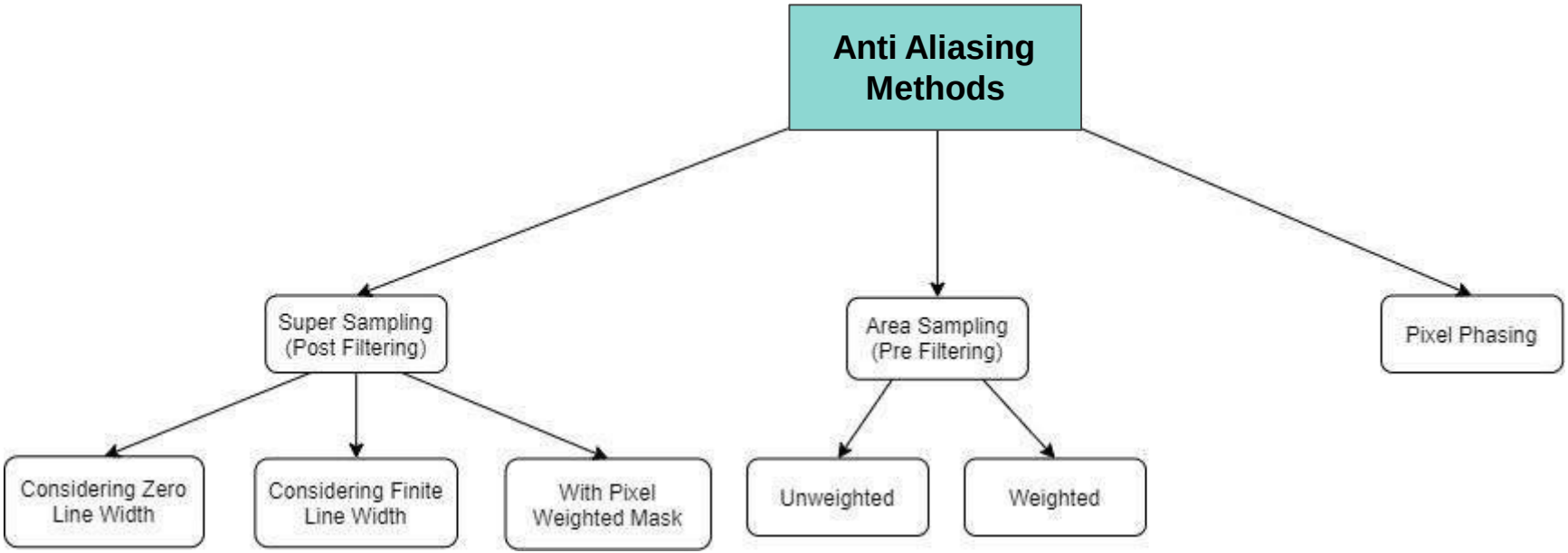
What is aliasing

In computer graphics, the process by which smooth curves and other lines become jagged because the resolution of the graphics device or file is not high enough to represent a smooth curve.

In the line drawing algorithms, we have seen that all rasterized locations do not match with the true line and we have to select the optimum raster locations to represent a straight line. This problem is severe in low resolution screens. In such screens line appears like a stair-step, as shown in the figure below. This effect is known as **aliasing**. It is dominant for lines having gentle and sharp slopes.



Anti - Aliasing



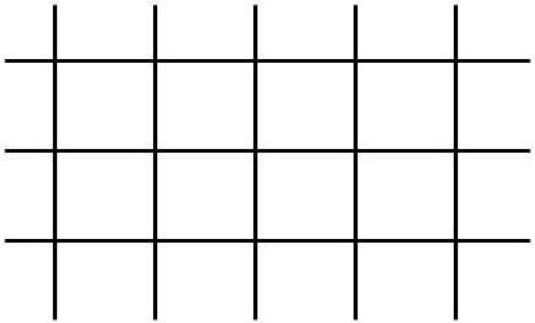
Super - Sampling

•Post Filtering first super samples the signal in its unfiltered form and then filters out the high frequency from the supersamples.

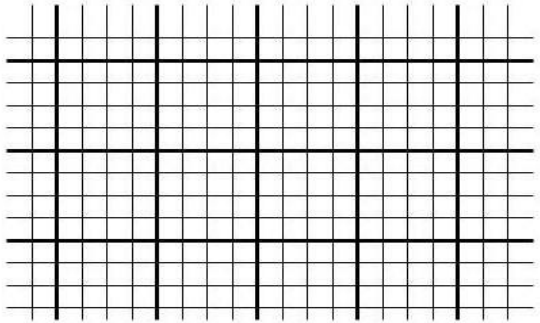
•Increase the sampling rate by treating the screen as if it had a finer grid resolution than is actually available

Super - Sampling

- Split single pixel into sub-pixels.
- Pixel's final color is a mixture of sub-pixels' colors. Simple method: Sample at the middle of each sub-pixel. Then, pixel's color is the average of the sub-pixels' color.

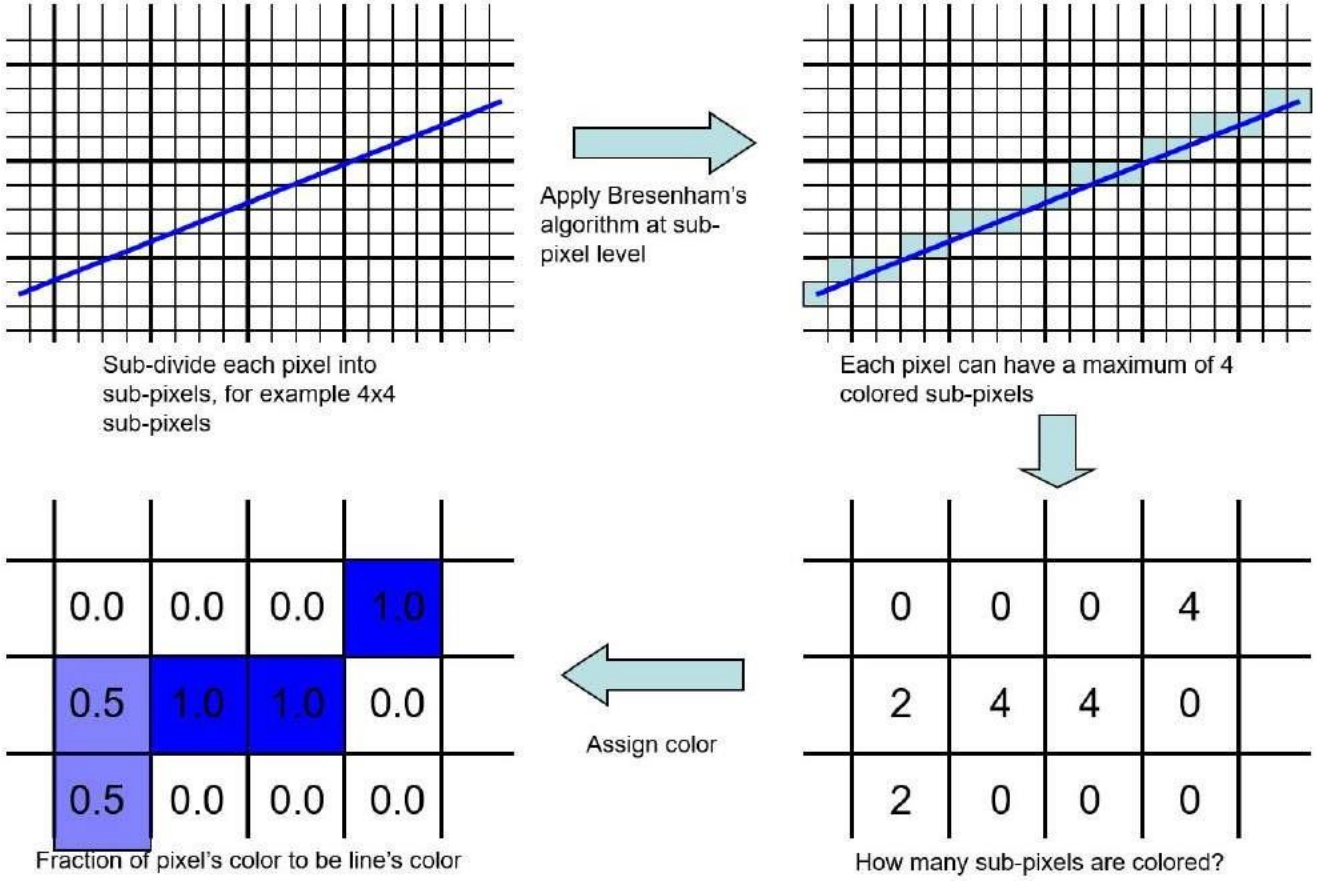


Pixels



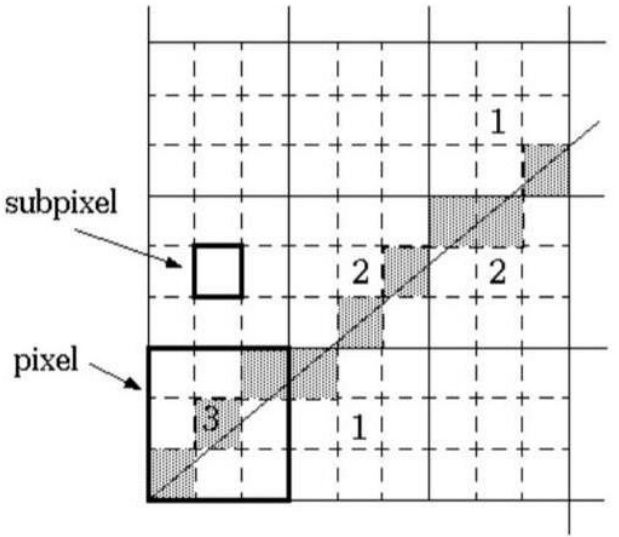
Sub-divide into sub-pixels

Super-Sampling a Zero-Width Line



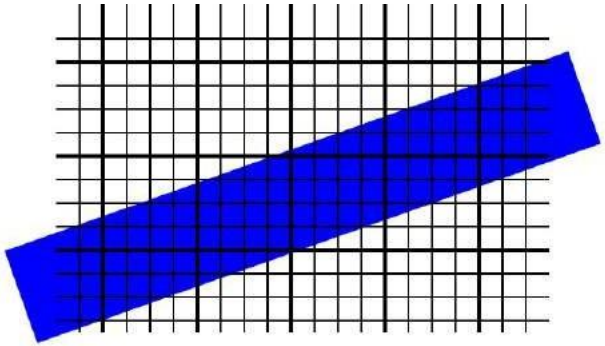
Super-Sampling a Zero-Width Line

- Example: a straight line on a gray scale display
- Divide each pixel into sub-pixels.
- The number of intensities are the max number of sub-pixels selected on the line segment within a pixel.

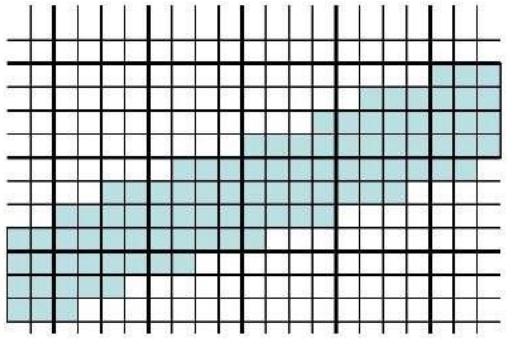


Subpixels selected by Bresenham's algorithm

Super-Sampling a Line with Non-Zero Width



A line that is one-pixel wide.
For every pixel: Maximum number of sub-pixels inside line = 16



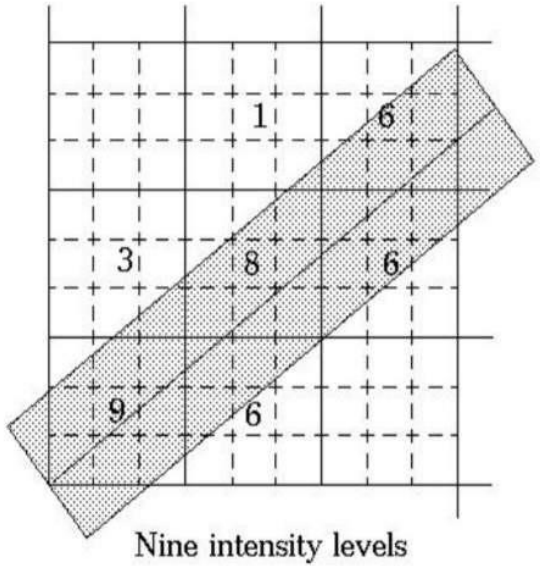
A sub-pixel is considered in if its lower-left corner is inside the line

	0	0	5/16	9/16	
	10/16	15/16	13/16	7/16	
	8/16	2/16	0	0	

Fraction of sub-pixels are in = fraction of color of the pixel should be line color

Super-Sampling a Line with Finite Width

- The intensity level for each pixel is proportional to the number of sub-pixels inside the polygon representing the line area.
- Line intensity is distributed over more pixels.



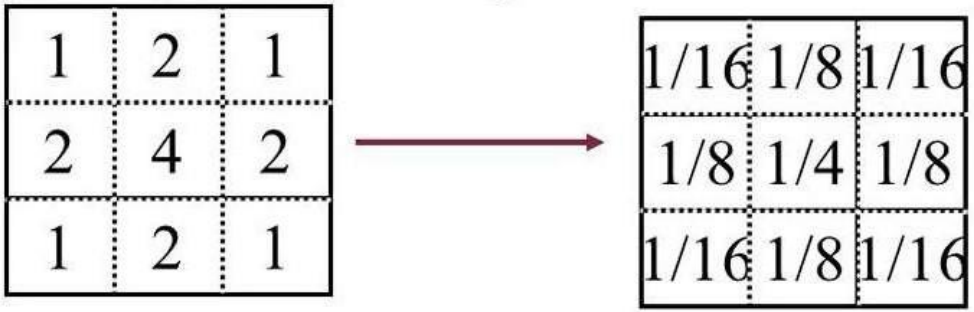
Nine intensity levels

Disadvantages with Finite Width

- More calculations involved to identify interior pixels.
- Positioning of the line depends on the slope of the line.
  - 45° - line centered in polygon
  - Horizontal or vertical line
    - line path on polygon boundary
  - $|m| < 1$
    - line path closer to lower boundary
  - $|m| > 1$
    - line path closer to upper boundary

Pixel Weighted Mask

- Give More Weight to Subpixels Near the Center of a Pixel Area
- Sum of the weights in the filter =1
- Low pass Filtering



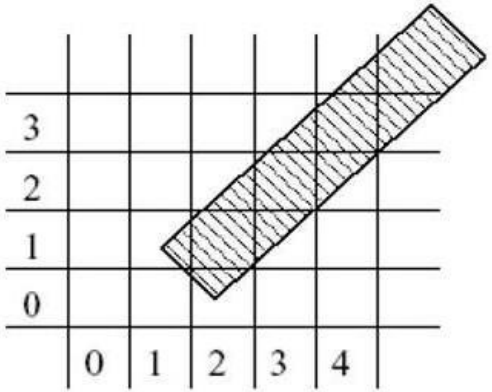
Area Sampling

- Central idea is to consider the pixel as an area, not a point, and calculate the pixel colour value from a weighted sum of the colours present inside the area.
  - e.g. In line-drawing, think of the line as a long rectangle, not the minimal line of pixels found by Bresenham’s method. Pixels partly covered by this rectangle would be shaded grey

Area Sampling

In the sample figure, the percentage of the pixel area covered by the line segment is used to determine the intensity level of the pixel.

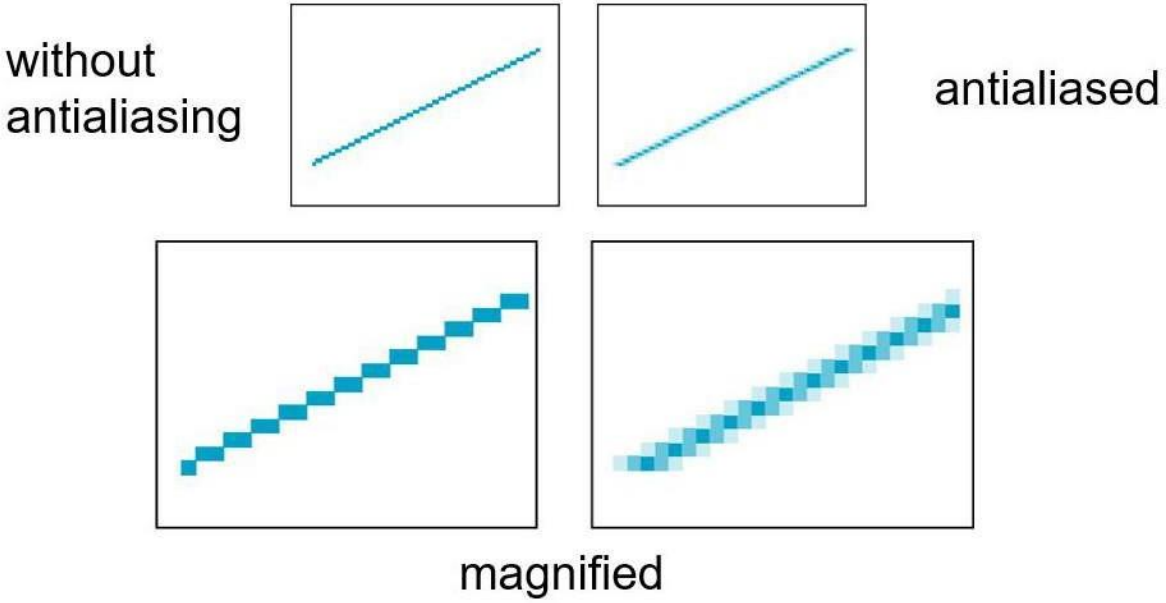
If multiple objects contribute to one pixel, then the intensities are weighed appropriately.



Pixel	% of Full Intensity
(1,0)	10%
(1,1)	20%
(2,0)	20%
(2,1)	90%
(2,2)	40%
(3,1)	50%
(3,2)	90%
(3,3)	30%

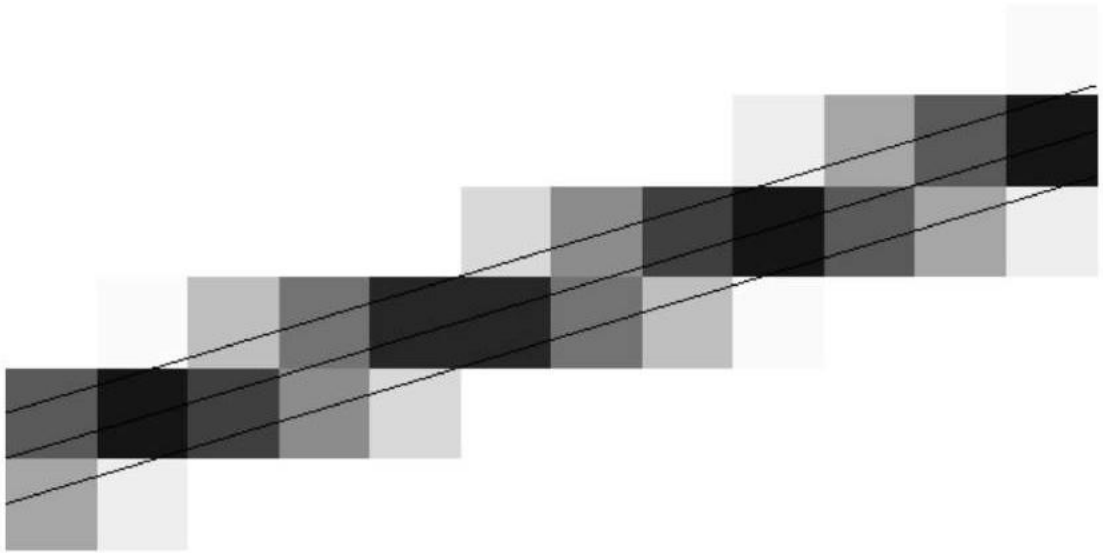
Area Sampling

Color multiple pixels for each x depending on coverage by ideal line



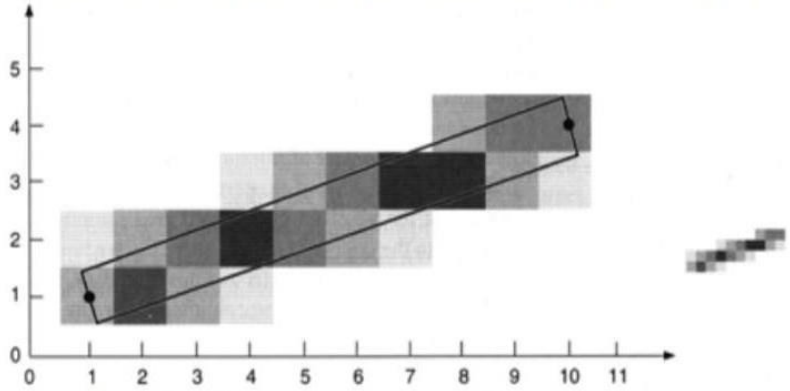
Unweighted Area Sampling

Here we consider instead of the mathematically infinitely thin line a line with some thickness, i.e. a small rectangle. We color each pixel according to the area of the corresponding unit square which is covered by this rectangle. It treats a pixel as an area, and compute pixel color based on the overlap of the scene's object with the pixel area. Equal areas contribute equal intensity, regardless of distance between the pixel's center and the area; only the total amount of overlapped area matters .



Unweighted Area Sampling

1. The intensity of a pixel decreases as the distance between the pixel center and the edge increases.
2. The primitive must intersect the pixel to have some effect.
3. Equal areas contribute equally to the pixel intensity.



Intensity of a pixel is proportional to its area covered by the line

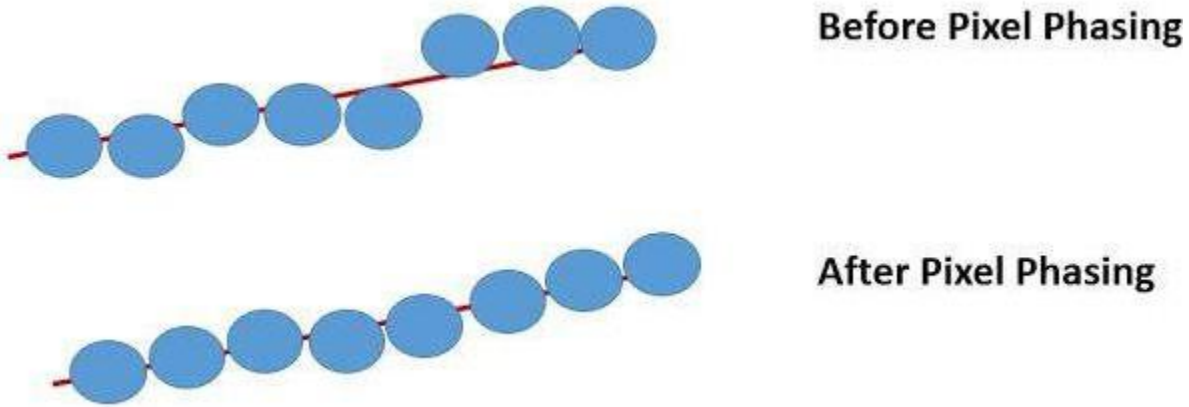
Weighted Area Sampling

Equal areas contribute unequally. A smaller area closer to the pixel center has a greater influence than does one at greater distance.

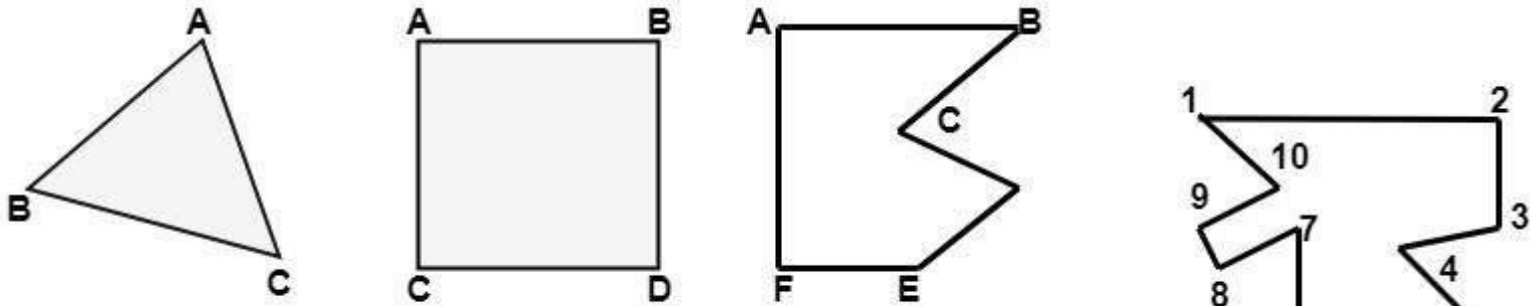
Pixel Phasing

- Some raster systems can address subpixel positions within the screen grid
- Smoothing is accomplished by moving pixel positions closer to the line path
- Electron beam is shifted by a fraction of a pixel diameter, typically ¼, ½, or ¾
- This plots points closer to the true path of a line

Pixel Phasing

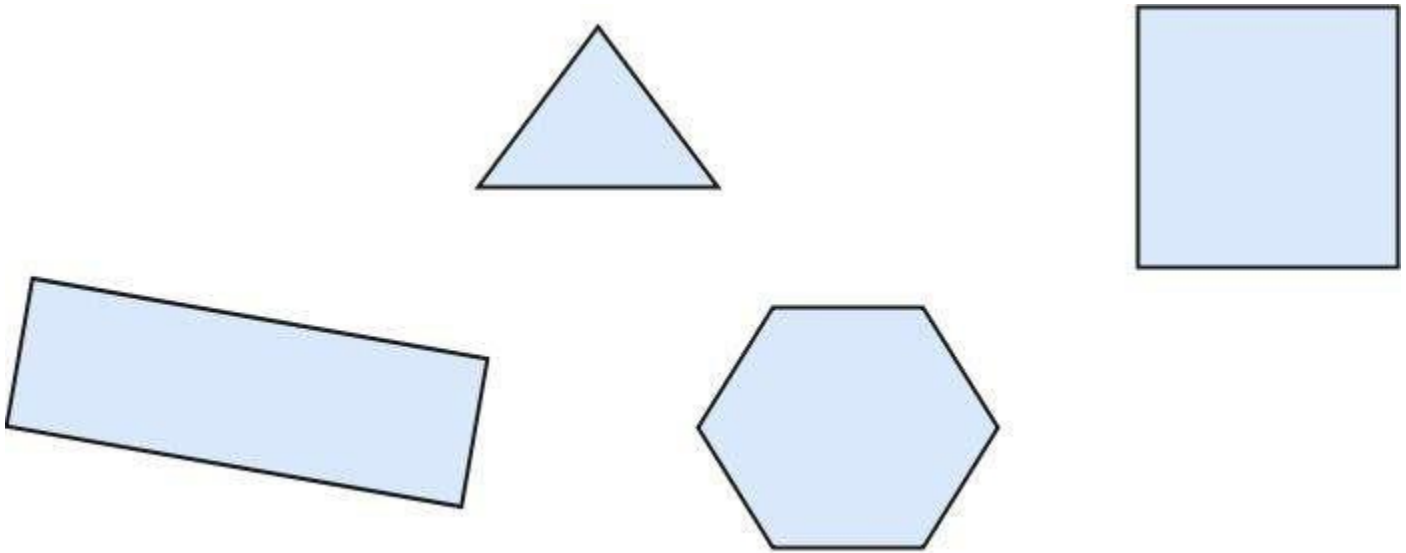


Types of Polygon



Polygons

Convex Polygon

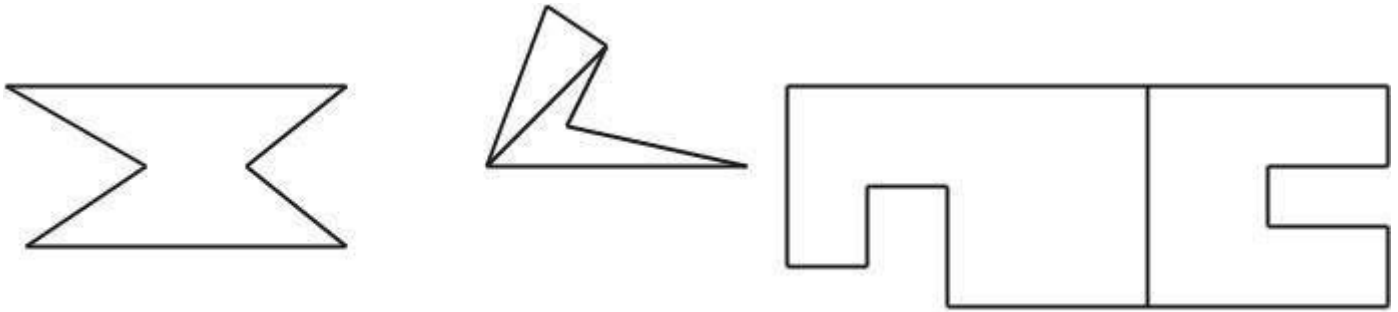


Convex Polygon

Consecutive Edges make an angle less than 180 degree

Connecting any two points inside the polygon will always give a line inside the polygon.

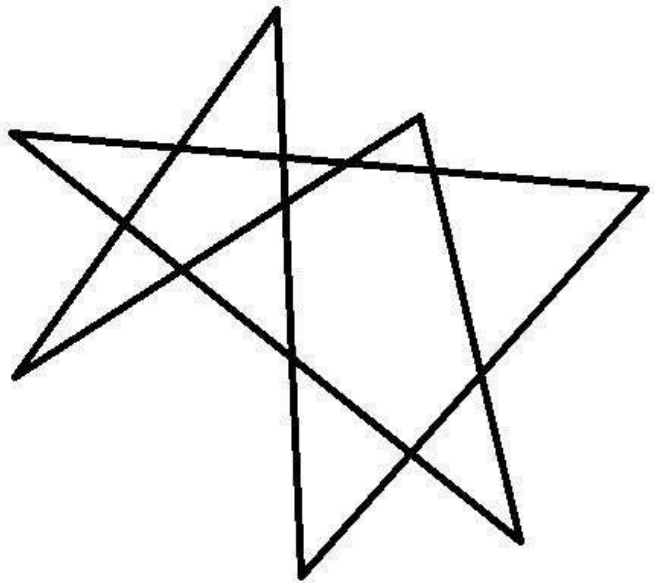
Concave Polygon



Concave Polygon

At Least one Consecutive Edge makes an angle greater than 180 degree
Connecting any two points inside the polygon will NOT always give a line inside the polygon.

Complex Polygon

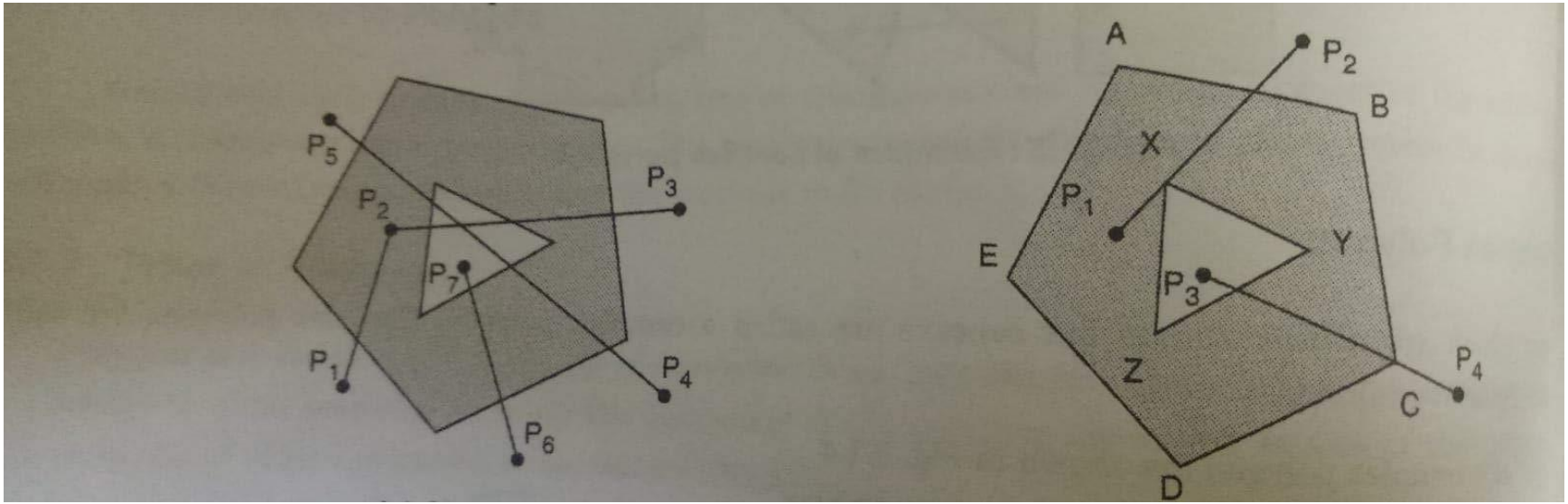


Does not fit into the criteria of Convex or Concave Polygon

Inside Outside Tests

- **EVEN ODD TEST**
- **WINDING NUMBER RULE**

EVEN ODD TEST



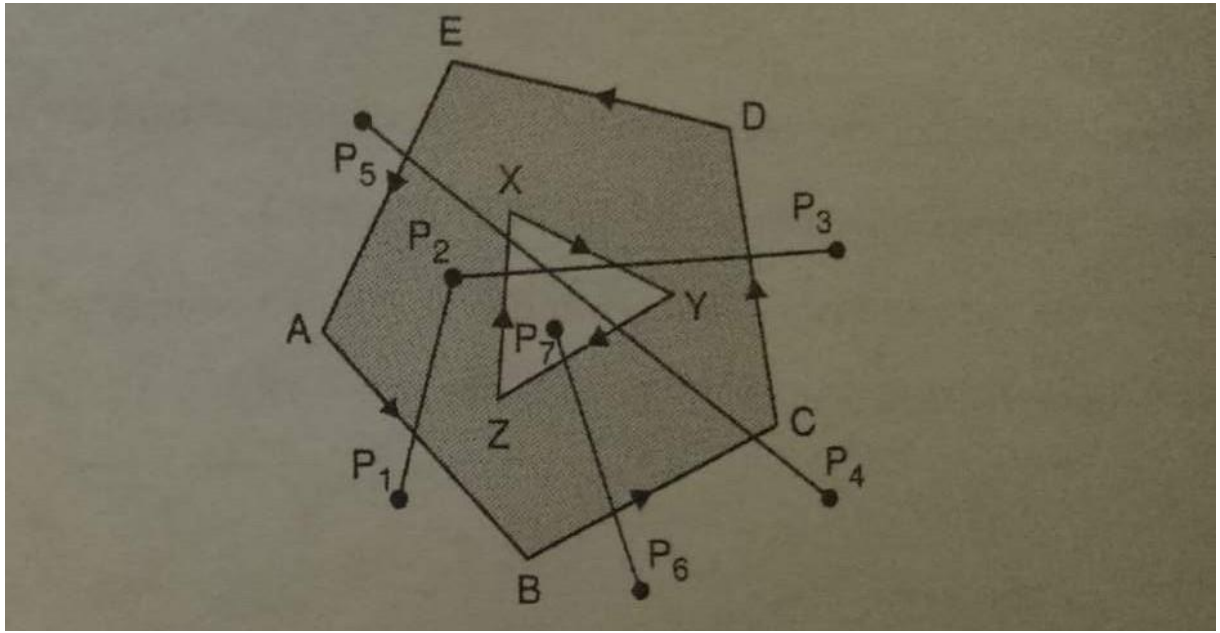
EVEN ODD TEST

Consider a point and join it to a known exterior point by drawing a line segment.

Get the count of the intersections of the line segment with the polygon edges;
If count is odd, the point is interior
If count is even, the point is exterior

For intersection at vertex;
If both edges are on the same side of the line then count as two intersections
If both edges are on the opposite side of the line then count as one intersection

Winding Number Rule



Winding Number Rule

Consider a point and join it to a known exterior point by drawing a line segment. Imagine a thread from the considered point and wind it around the outermost boundary of polygon in anti-clockwise direction and inner boundary if exists in clockwise direction.
Get the count of the intersections of the line segment from left to right(Clockwise direction edges) and right to left (Anti-clockwise direction edges),

Calculate the difference, If the difference is zero then point is an exterior point
Else for non zero value of difference, the point is interior point

References

- Hearn & Baker, “Computer Graphics C version”, 2nd Edition, Pearson Publication