SCAN CONVERSION - POLYFILL
Pixels are not at the center of the grid, but at the intersection of two orthogonal scan lines (on the grid intersection points).
SCANLINE POLYFILL ALGORITHM

Steps (conceptual):

• Find minimum enclosed rectangle

• No. of scanlines = \( Y_{\text{max}} - Y_{\text{min}} + 1 \)

• For each scanline do
  
  • Obtain intersection points of scanline with polygon edges.

  • Sort intersections from left to right

  • Form pairs of intersections from the list§

  • Fill within pairs

  • Intersection points are updated for each scanline

  • Stop when scanline has reached \( Y_{\text{max}} \)

§ - Intersections at vertices require special handling

Check if a point is within a Poly?

Look left or right, and count the number of intersection points of the scanline with the edges of the Poly.

If the number is ODD, Points is Inside else Outside
Two different cases of scanlines passing through the vertex of a polygon

Add one more intersection: 3 -> 4

Add one more intersection: 5 -> 6; ---->

Do not add intersection, keep 4; ----> HOW ??
For $Y$, the edges at the vertex are on the same side of the scanline, whereas for $Y'$ the edges are on either/both sides of the vertex. In this case, we require additional processing:

Traverse along the polygon boundary clockwise (or counterclockwise) and observe the relative change in $Y$-value of the edges on either side of the vertex (i.e. as we move from one edge to another).

Check the condition:

*If end-point $Y$ values of two consecutive edges monotonically increase or decrease, count the middle vertex as a single intersection point for the scanline passing through it.*

*Else the shared vertex represents a local maximum (or minimum) on the polygon boundary.*
If the vertex is a local extrema, add two intersections for the scan line corresponding to such a shared vertex.

Must avoid this to happen in cases, such as:

Before processing

After processing

To implement the above:

While processing non-horizontal edges (generally) along a polygon boundary in any order, check to determine the condition of monotonically changing (increasing or decreasing) endpoint Y values. If so:

Shorten the lower edge to ensure only one intersection point at the vertex.
Scanline Fill Algorithm (revisited, in brief)

Intersect scanline with polygon edges.
Fill between pairs of intersections

Basic Structure:
For y = \( Y_{\text{min}} \) to \( Y_{\text{max}} \)
  1) intersect scanline with each edge
  2) sort intersections by increasing X
  3) fill pairwise ( int0->int1, int2->int3, ... )

This is the basic structure, but we are going to handle some special cases to make sure it works right.

- **scanline coherence** - values don't change much from one scanline to the next - the coverage (or visibility) of a face on one scanline typically differs little from the previous one.

- **edge coherence** - edges intersected by scanline \( i \) are typically intersected by scanline \( i+1 \)
Slope of the line $L$ (polygon edge) is:

$$m = \frac{Y_{k+1} - Y_k}{X_{k+1} - X_k}$$

where, $Y_{k+1} = Y_k + 1$; Thus, $X_{k+1} = X_k + 1/m$

Thus the intersection for the next scanline is obtained as:

$$X_{k+1} = \text{round}(X_k + 1/m),$$

where $m = \Delta Y/\Delta X$. How to implement this using integer arithmetic?

Take an example: $m = \Delta Y/\Delta X = 7/3$.
Set Counter, $C = 0$ and counter increment, $\Delta C = \Delta X = 3$;

For the next three scan lines, successive values of $C$ are: 3, 6, 9. Thus only at $3^{rd}$ scanline $C > \Delta Y$.
$X_k$ is incremented by 1 only at $3^{rd}$ scanline and set $C = C - \Delta Y = 9 - 7 = 2$.

Repeat the above step(s) till $Y_k$ reaches $Y_{\text{max}}$. 
Data Structure Used (typical example):

**SET (Sorted Edge table):**
Contains all information necessary to process the scanlines efficiently. SET is typically built using a bucket sort, with a many buckets as there are scan lines. All edges are sorted by their $Y_{\text{min}}$ coordinate. with a separate Y bucket for each scanline. Within each bucket, edges sorted by increasing X of $Y_{\text{min}}$ point.

Only non-horizontal edges are stored. Store these edges at the scanline position in the SET.

**Edge structure** (sample record for each scanline):
$(Y_{\text{max}}, X_{\text{min}}, \Delta X/\Delta Y, \text{pointer to next edge})$

**AEL (Active edge List):**
Contains all edges crossed by a scanline at the current stage of iteration. This is a list of edges that are active for this scanline, sorted by increasing X intersections. Also called: **Active Edge Table (AET).**
<table>
<thead>
<tr>
<th>y coordinate</th>
<th>( \lambda )</th>
<th>( \lambda )</th>
<th>( \lambda )</th>
<th>( \frac{5}{2} )</th>
<th>( \frac{4}{2} )</th>
<th>( \frac{3}{2} )</th>
<th>( \frac{2}{2} )</th>
<th>( \frac{1}{2} )</th>
<th>( \frac{0}{2} )</th>
<th>( \frac{-1}{2} )</th>
<th>( \frac{-2}{2} )</th>
<th>( \frac{-3}{2} )</th>
<th>( \frac{-4}{2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \lambda )</td>
<td>( \lambda )</td>
<td>( \lambda )</td>
<td>9 7 ( \frac{5}{2} )</td>
<td>11 7 ( \frac{7}{2} )</td>
<td>( \lambda )</td>
<td>11 13 0 ( \lambda )</td>
<td>( \lambda )</td>
<td>9 2 0 ( \lambda )</td>
<td>( \lambda )</td>
<td>3 7 ( \frac{5}{2} )</td>
<td>5 7 ( \frac{7}{2} )</td>
<td>( \lambda )</td>
</tr>
</tbody>
</table>

AET pointer

<table>
<thead>
<tr>
<th></th>
<th>FA</th>
<th>EF</th>
<th>DE</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 2 0</td>
<td>9 2 ( \frac{5}{2} )</td>
<td>11 10 ( \frac{4}{2} )</td>
<td>11 13 0 ( \lambda )</td>
<td></td>
</tr>
</tbody>
</table>

Scan line

(a)
Precautions:
Intersection has an integer Y coordinate
  If this point is the \( Y_{\text{min}} \) of the edge's endpoints, count it.
  \textbf{If the edge is horizontal and on the scanline, don't count it.}

During iteration process with each scanline, the \textit{AET is updated}. For each scanline the AET keeps track of the set of edges it has to intersect and stores the intersection points in it. The sorting of the entries is w.r.t the X-intersection values.

Have a closer look at it, w.r.t. the previous figure:

\begin{itemize}
  \item \textbf{Scanline No. 8:}
  \begin{itemize}
    \item AET Pointer
    \begin{itemize}
      \item FA: 9 2 0
      \item EF: 9 4 -5/2
      \item DE: 11 9 6/4
      \item CD: 11 13 0 \( \lambda \)
    \end{itemize}
  \end{itemize}

  \item \textbf{Scanline No. 9:}
  \begin{itemize}
    \item AET Pointer
    \begin{itemize}
      \item FA: 9 2 0
      \item EF: 9 2 -5/2
      \item DE: 11 10 6/4
      \item CD: 11 13 0 \( \lambda \)
    \end{itemize}
  \end{itemize}

  \item \textbf{Scanline No. 10:}
  \begin{itemize}
    \item AET Pointer
    \begin{itemize}
      \item DE: 11 12 6/4
      \item CD: 11 13 0 \( \lambda \)
    \end{itemize}
  \end{itemize}
\end{itemize}
Processing Steps:

• Set Y to smallest Y in SET entry (first non-empty bucket)

• Initialize AET to be empty

• Repeat until both AET and SET are empty

  (i) Move from SET bucket Y to AET, those edges whose $Y_{\min} = Y$.

  (ii) Sort AET on X (simple, as SET is pre-sorted anyway).

  (iii) Fill pixels in scanline Y using pairs of X-coordns. from AET.

  (iv) Increment scanline by 1.

  (v) Remove from AET those entries for which $Y = Y_{\max}$ (edges not involved).

  (vi) For each non-vertical edge in AET, update X for new Y.
The algorithm: 
\text{scan-fill}(\text{polygon})

\begin{align*}
\text{Construct the Edge table (ET)} \\
Y &= \min(\text{all } Y \text{ in the ET}) \\
AET &= \text{null}
\end{align*}

\text{for } Y = Y_{\text{min}} \text{ to } Y_{\text{max}}

\begin{align*}
\text{Merge-sort } ET[Y] \text{ into } AET \text{ by } X \text{ value} \\
\text{Fill between pairs of } X \text{ in } AET.
\end{align*}

\text{for each edge in } AET
\begin{align*}
\text{if } \text{edge}.Y_{\text{max}} &= Y \\
\text{remove edge from } AET
\end{align*}
\text{else}
\begin{align*}
\text{edge}.X &= \text{edge}.X + \frac{dx}{dy}
\end{align*}
\text{endif}

\text{sort AET by } X \text{ value}

\text{end scan_fill}