Computing Mitered Offset Curves Based on Straight Skeletons

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Salzburg, Austria

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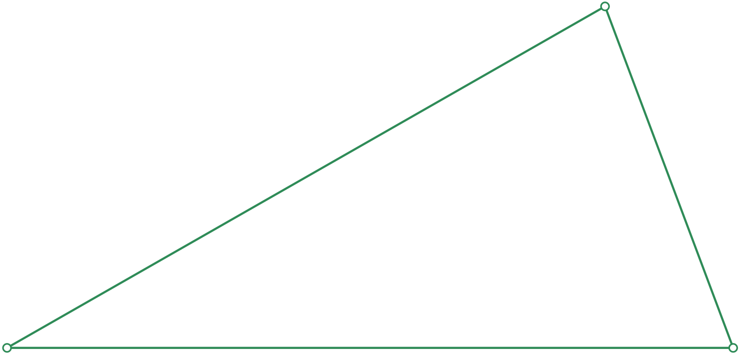
Computational Geometry and Applications Lab

Straight Skeletons — Motivation

Aichholzer&Alberts&Aurenhammer&Gärtner (1995)



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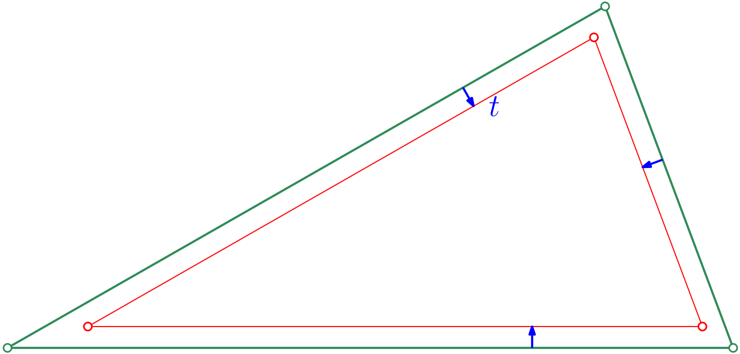

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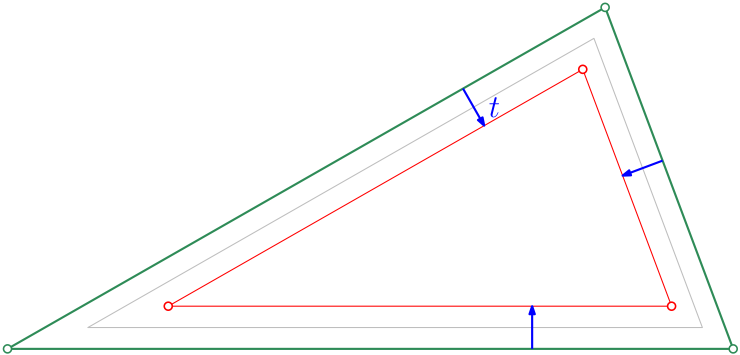

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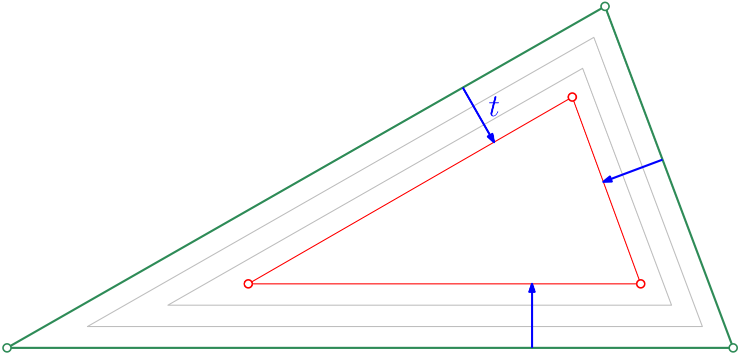

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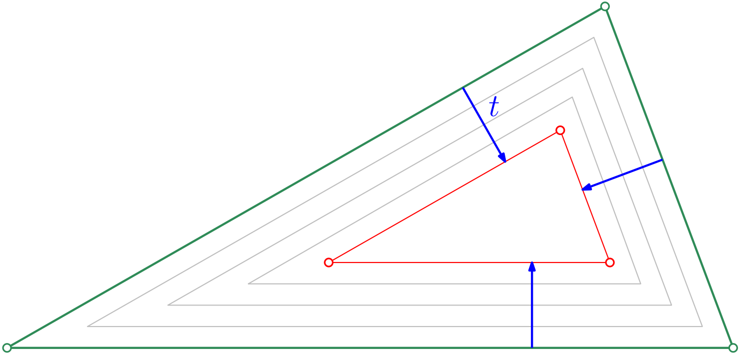

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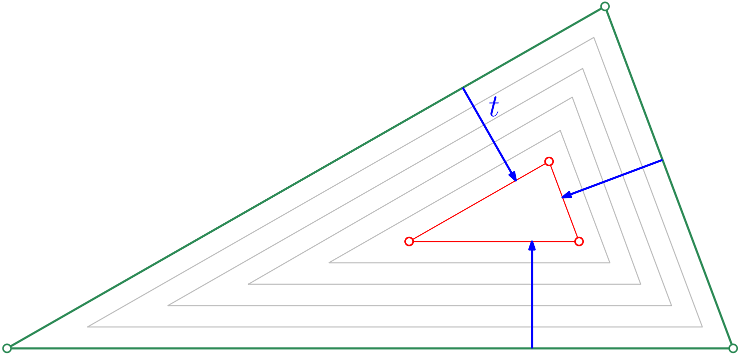

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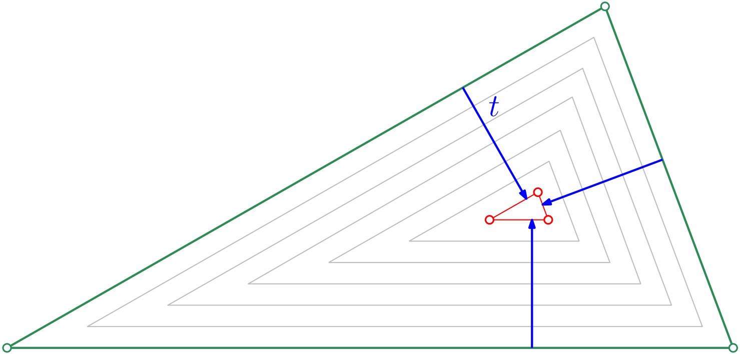

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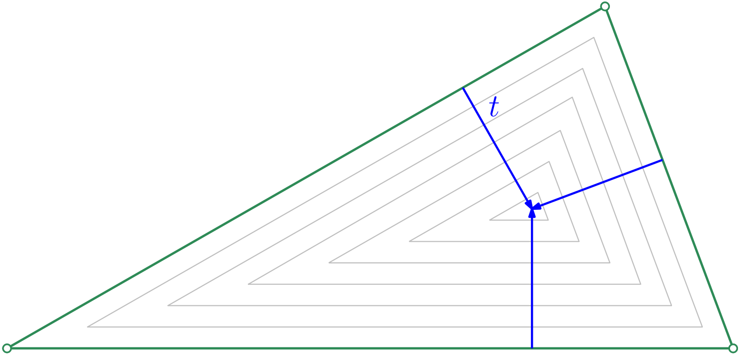

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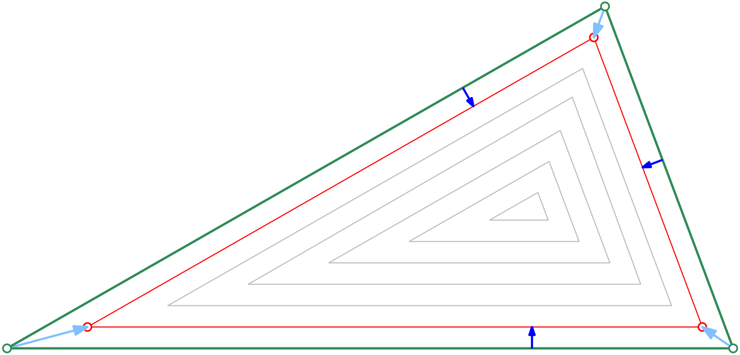

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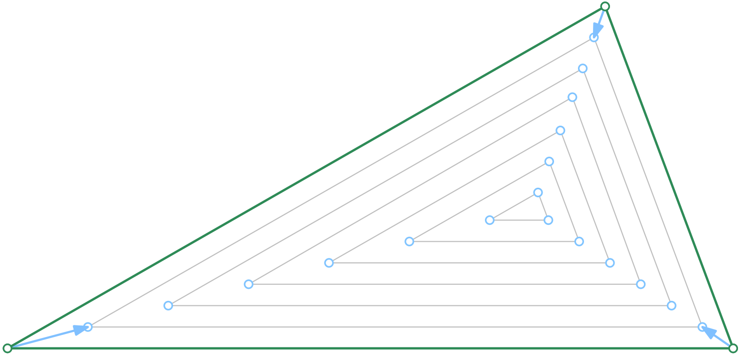

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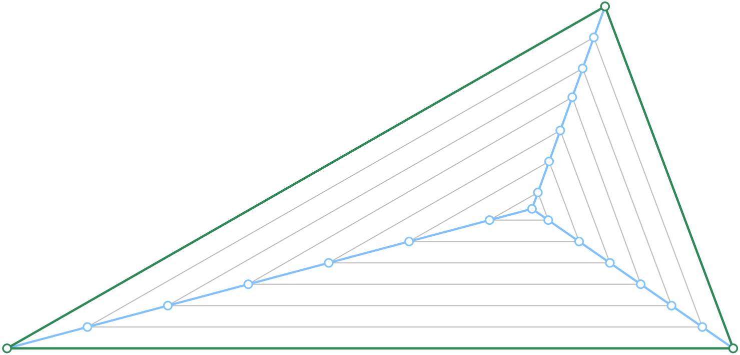
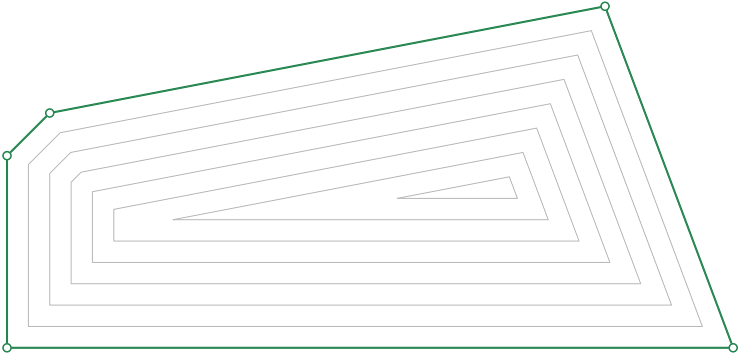
- Wavefront propagation with unit speed via continued offsetting: shrinking process, where offset distance t equals time.
- Straight skeleton $\mathcal{SK}(\mathcal{P})$ is union of traces of wavefront vertices.



Change of Wavefront Topology

Edge event

- Wavefront topology changes over time.



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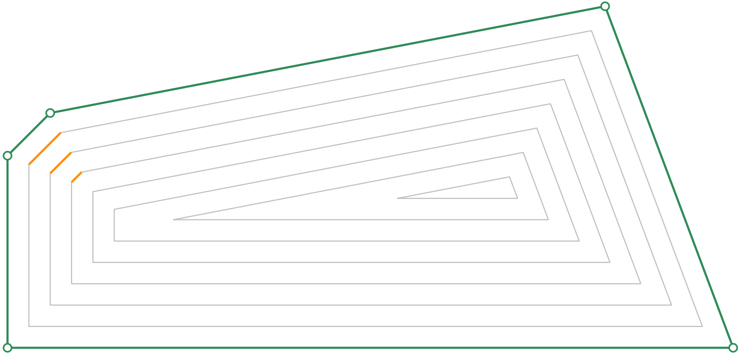

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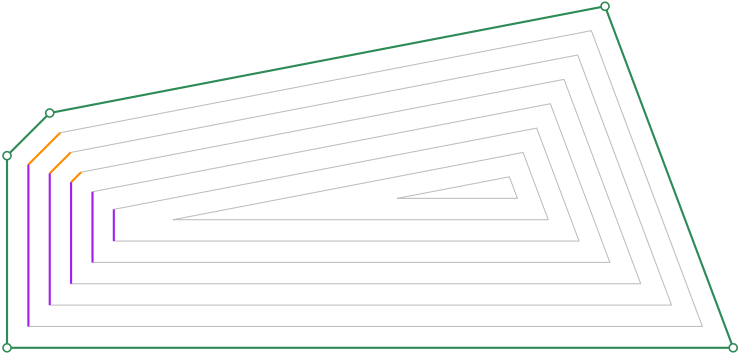
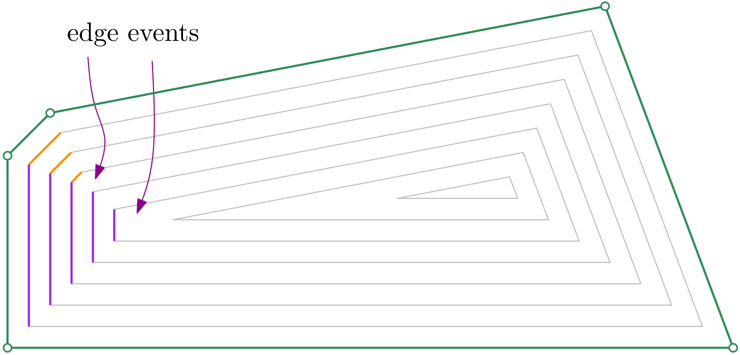


Change of Wavefront Topology

Edge event

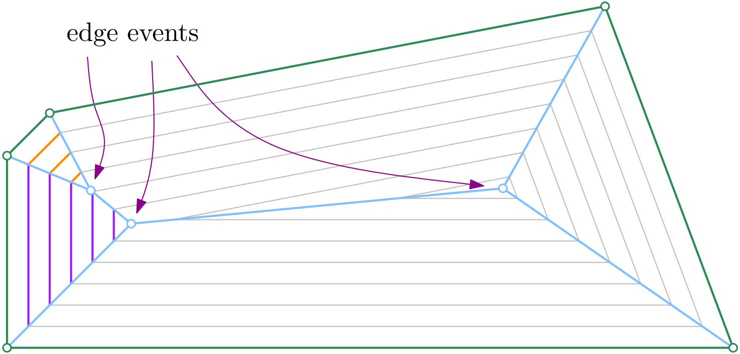
- Wavefront topology changes over time.
- *Edge event*: an edge of $\mathcal{WF}(\mathcal{P}, t)$ vanishes.



Change of Wavefront Topology

Edge event

- Wavefront topology changes over time.
- *Edge event*: an edge of $\mathcal{WF}(\mathcal{P}, t)$ vanishes.
- Such a change of topology corresponds to a *node* of $\mathcal{SK}(\mathcal{P})$.



Change of Wavefront Topology

Split event

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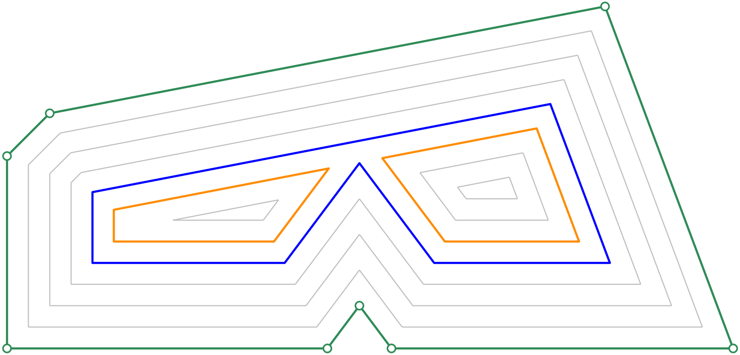
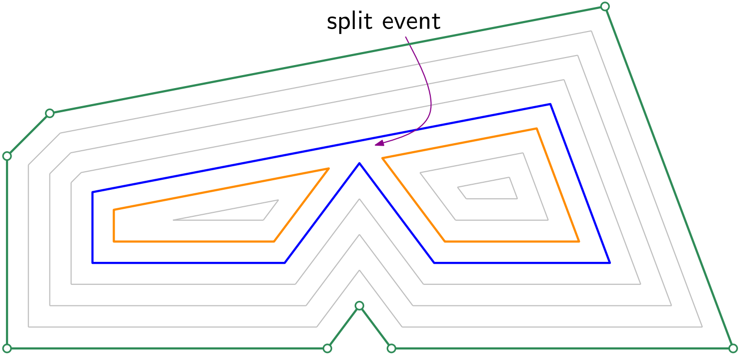


Change of Wavefront Topology

Split event

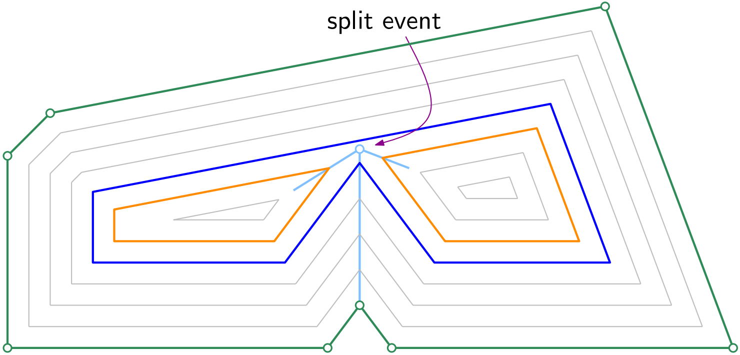
- Wavefront topology changes over time.
- *Split event*: wavefront splits into two parts.



Change of Wavefront Topology

Split event

- Wavefront topology changes over time.
- *Split event*: wavefront splits into two parts.
- Also split events correspond to *nodes* of $\mathcal{SK}(\mathcal{P})$.



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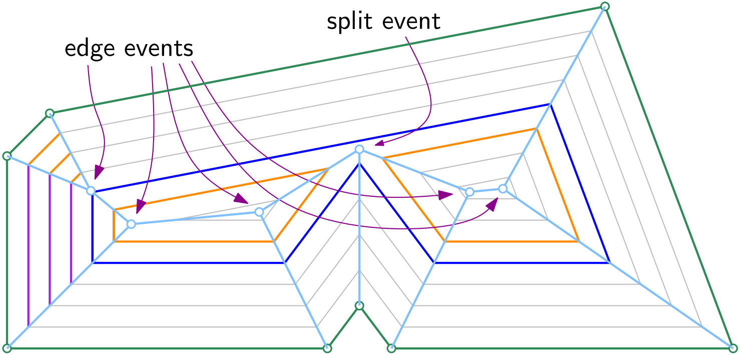
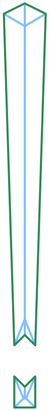
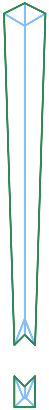


Straight Skeleton



Definition

The *straight skeleton* $\mathcal{SK}(\mathcal{P})$ of a polygon $\mathcal{P}$ is given by the union of traces of wavefront vertices of $\mathcal{P}$ over the entire wavefront propagation process.



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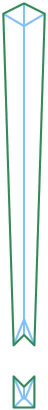

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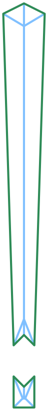

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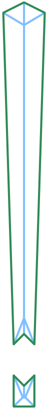

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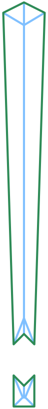

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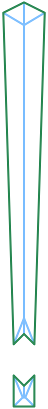

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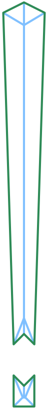
- No metric-based definition of straight skeletons exists.



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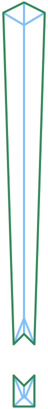

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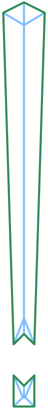
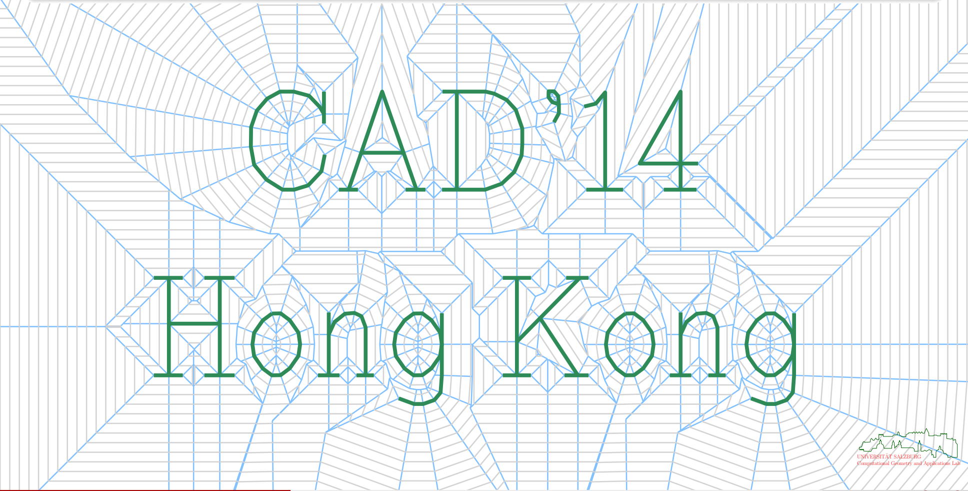
- No metric-based definition of straight skeletons exists.
- If $\mathcal{P}$ has n segments then $\mathcal{SK}(\mathcal{P})$ consists of $O(n)$ nodes and $O(n)$ straight-line edges.

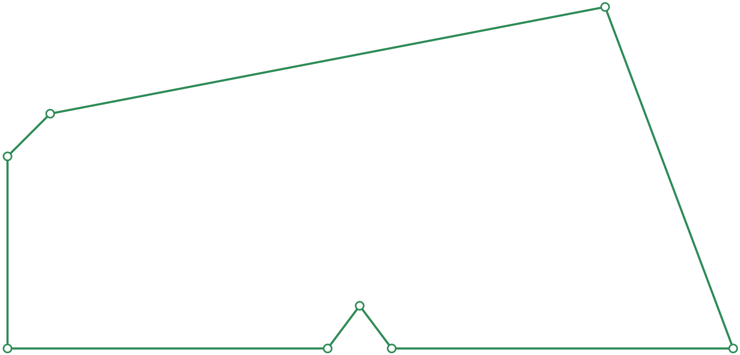


Straight Skeleton of a PSLG

The definition of straight skeletons can be extended easily to arbitrary planar straight line graphs (PSLGs) within the entire plane, i.e., to a collection of straight-line segments that do not intersect except possibly at common endpoints.



Computing Straight Skeletons



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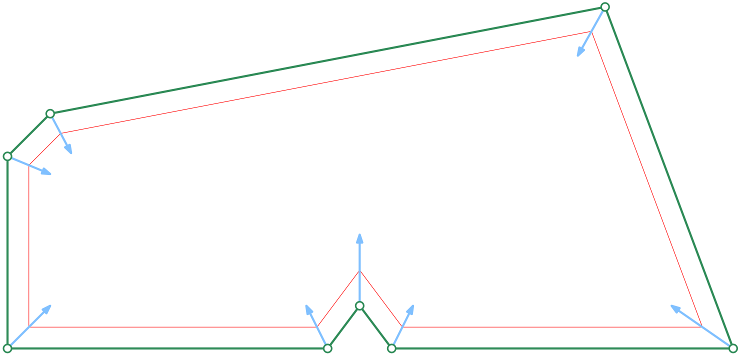
Basic idea

- Simulate the wavefront propagation.



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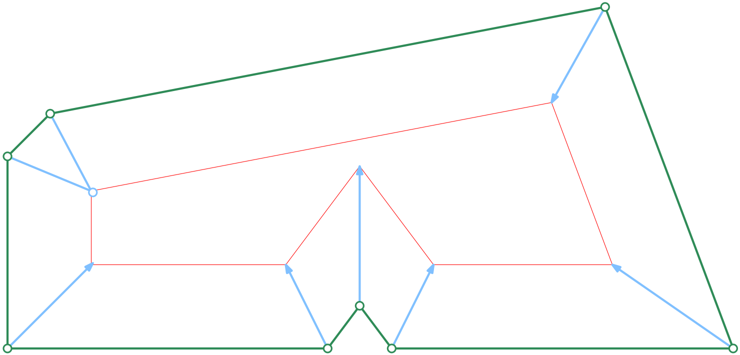
- Simulate the wavefront propagation.
- Problem: When will the next event happen? Which event?



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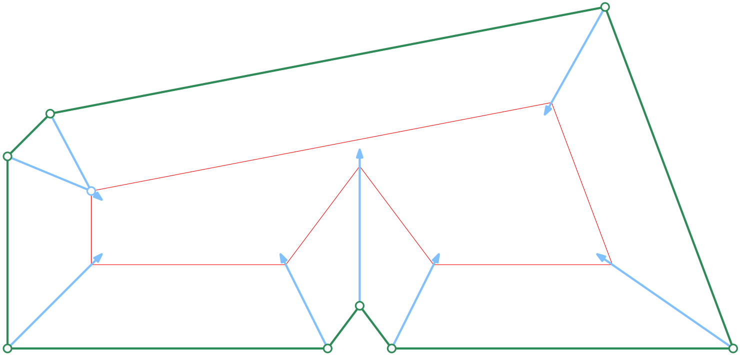
- If we can solve this problem then we can construct straight skeletons.



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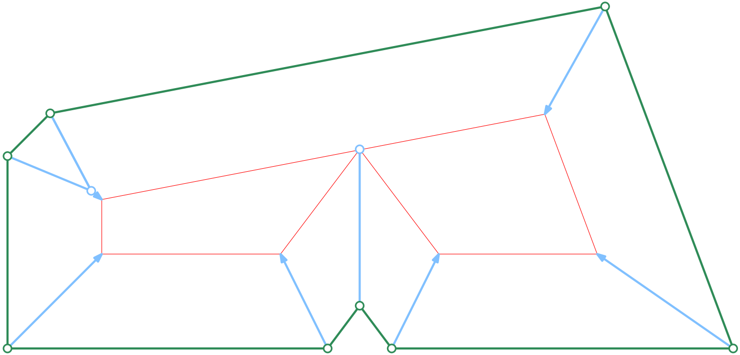

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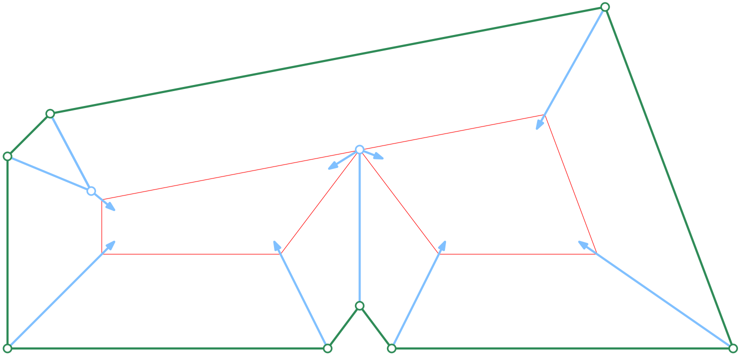

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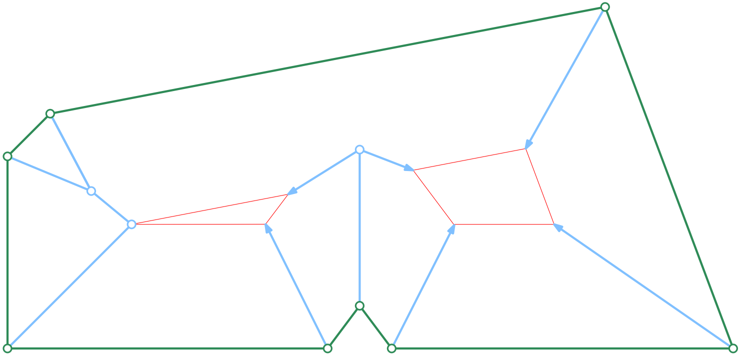

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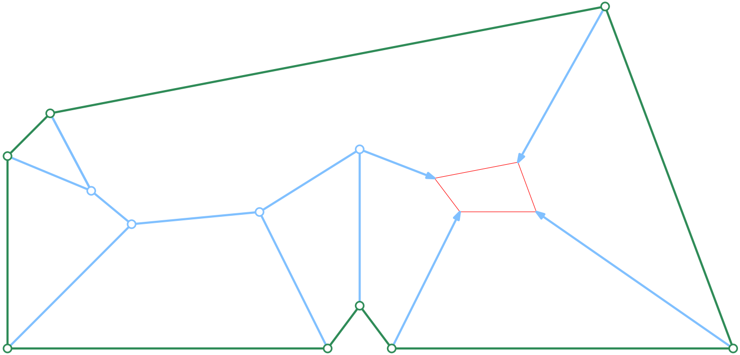

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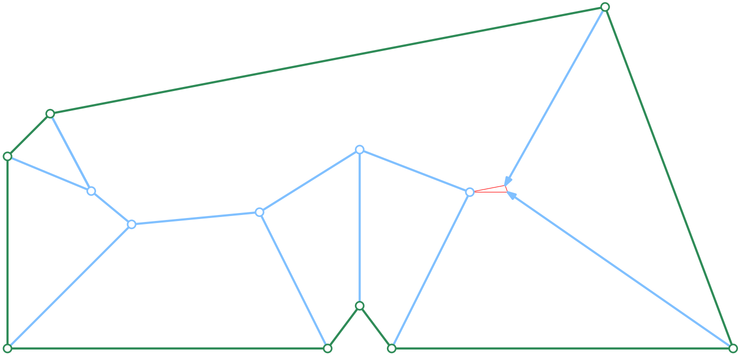

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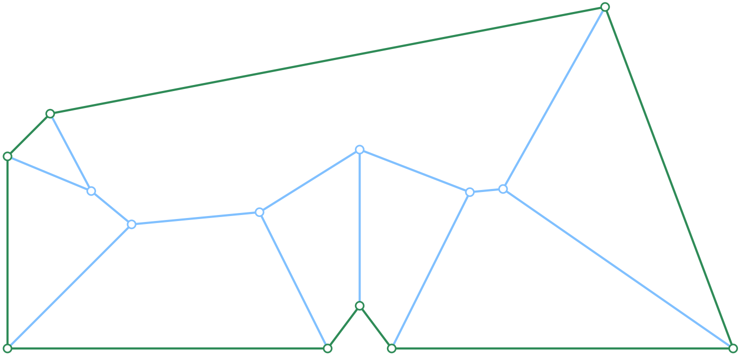
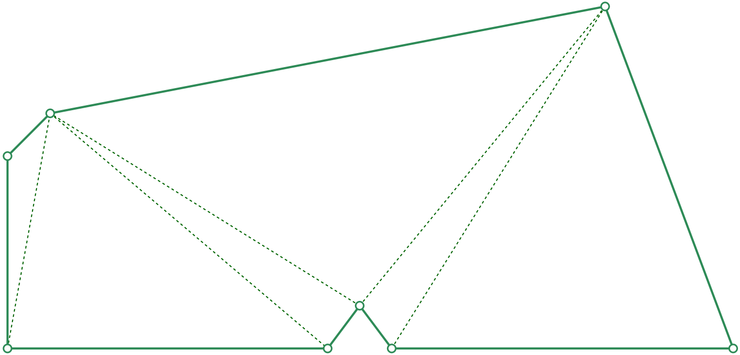


Triangulation-Based Algorithm

Aichholzer&Aurenhammer (1998)

- Maintain a kinetic triangulation of (the interior of) the wavefront.



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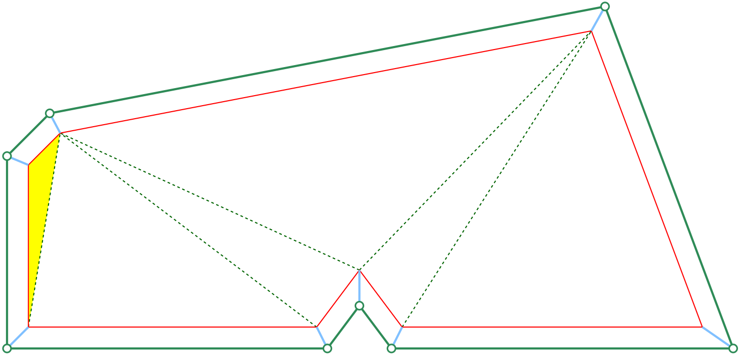

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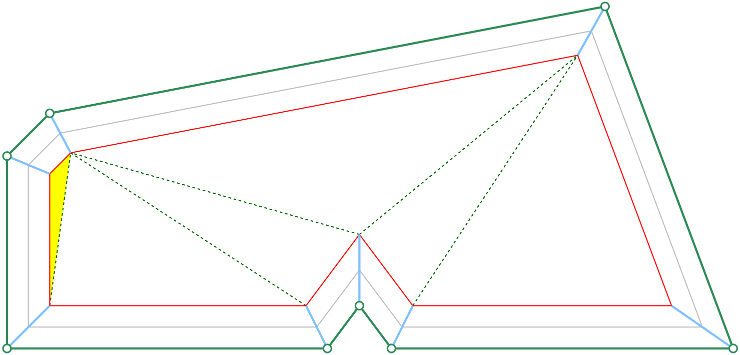

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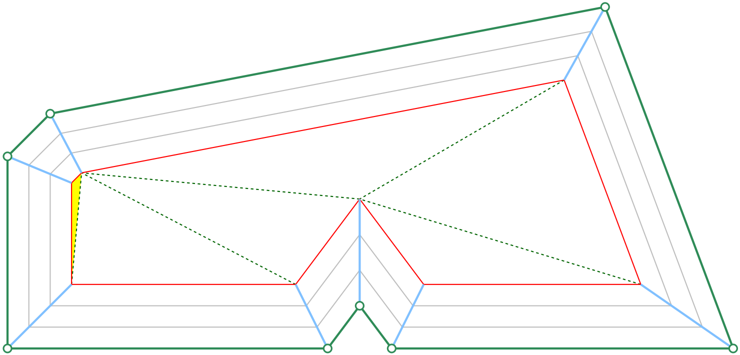

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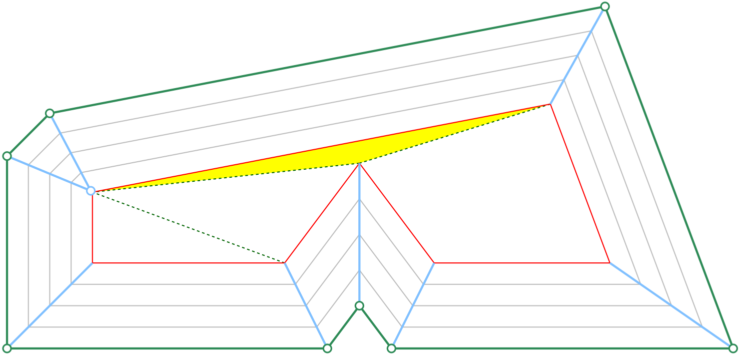

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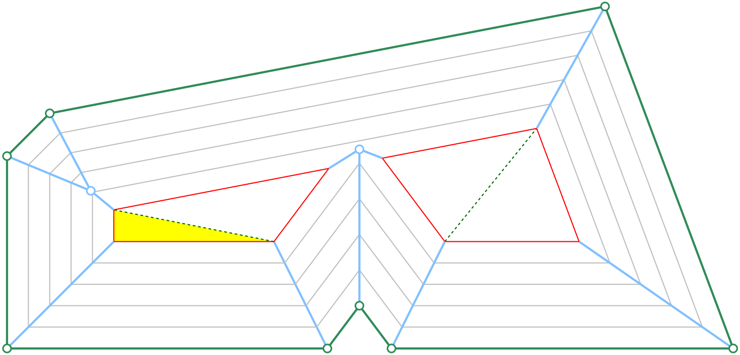

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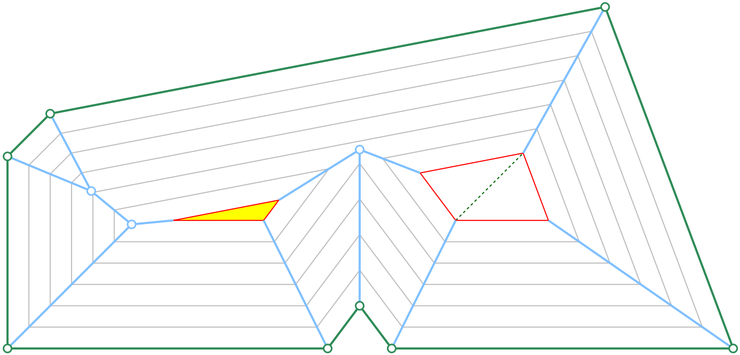

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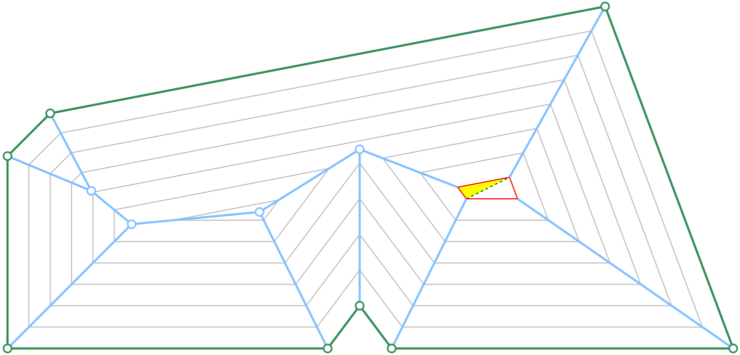

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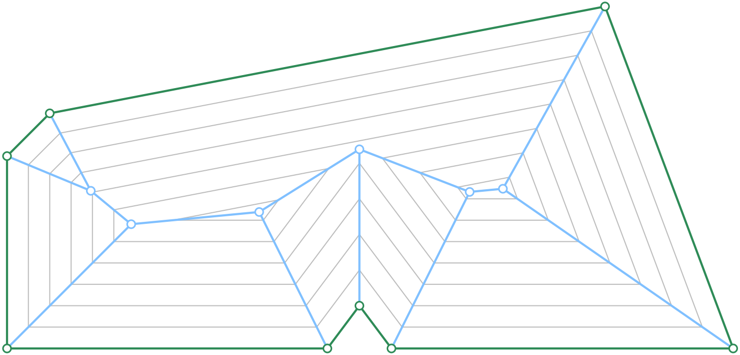

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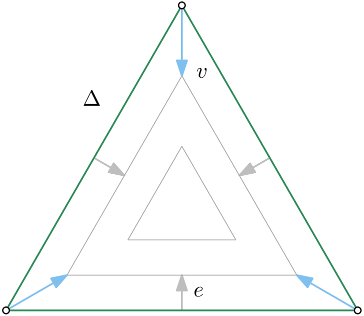

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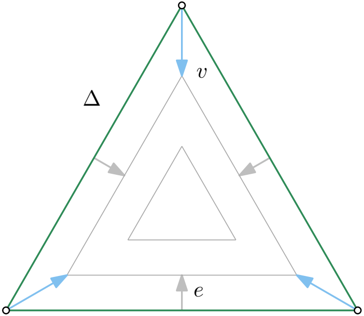

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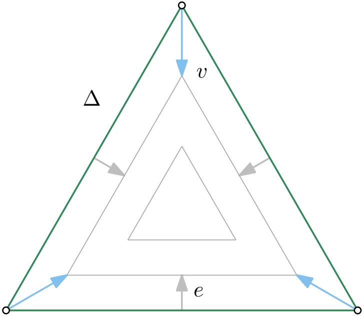

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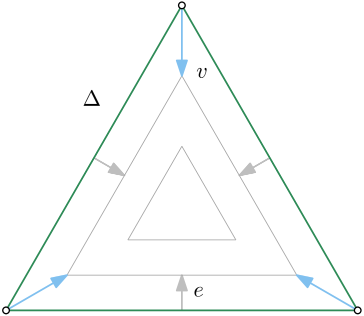

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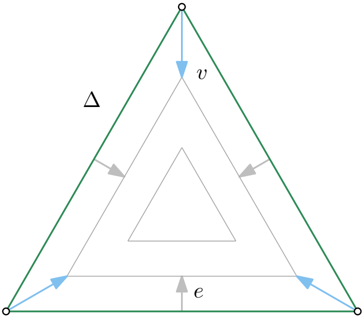


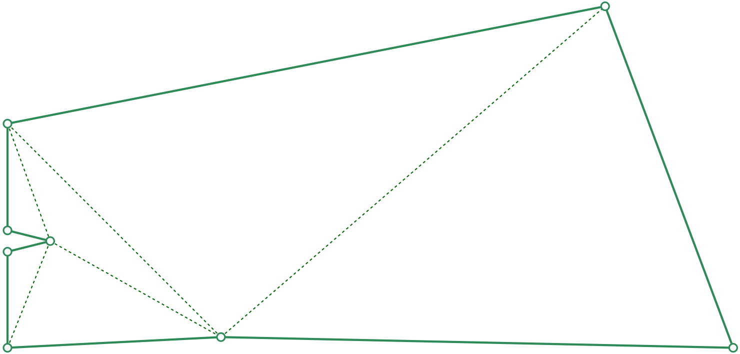
Algorithmic insight

Wavefront propagation based on kinetic triangulations allows to determine all events and to compute straight skeletons.

Triangulation-based Algorithm

Flip events

- Caveat: Not all collapses witness changes in the wavefront topology.



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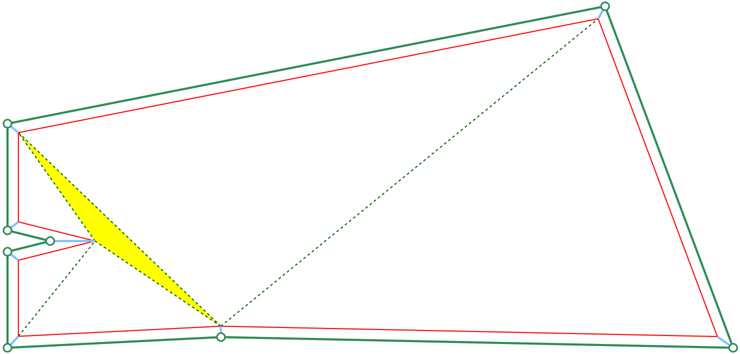

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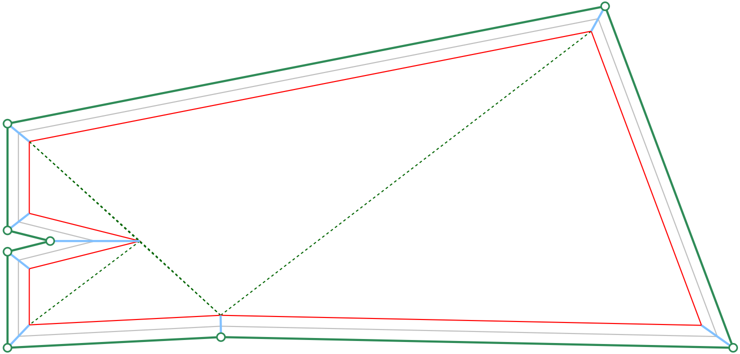

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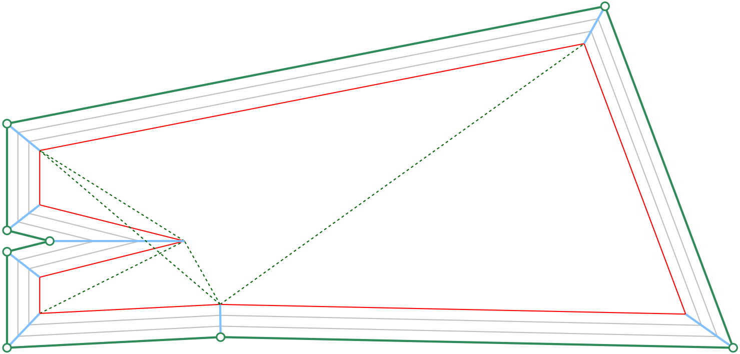

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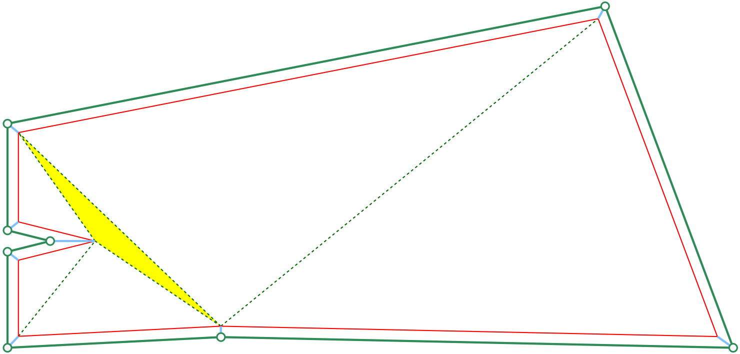

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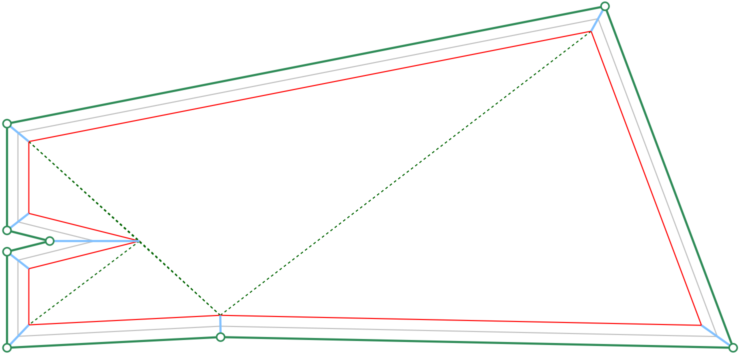

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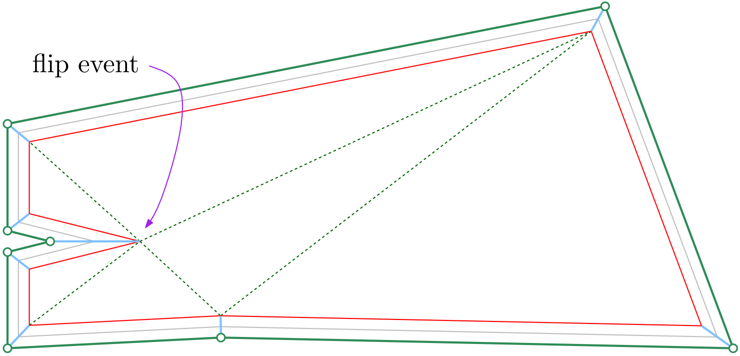

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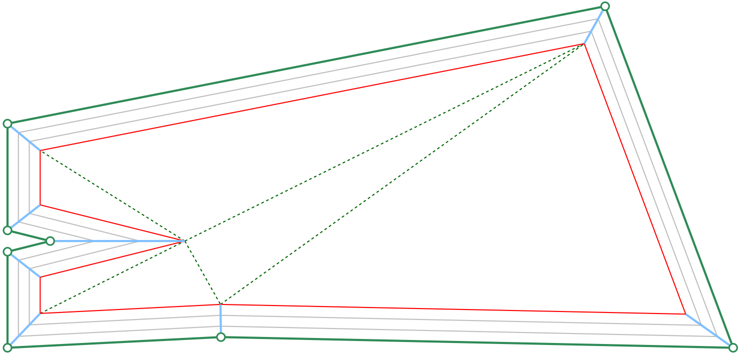

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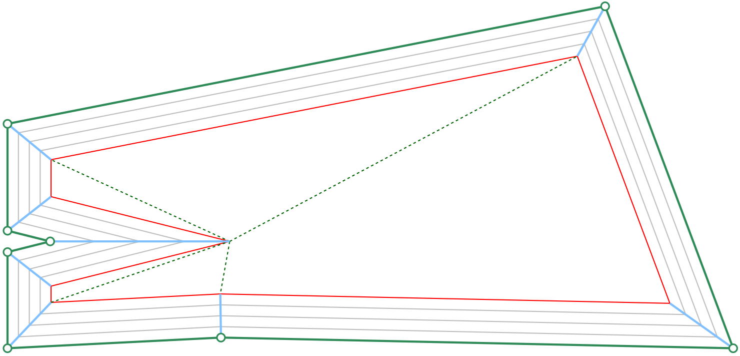

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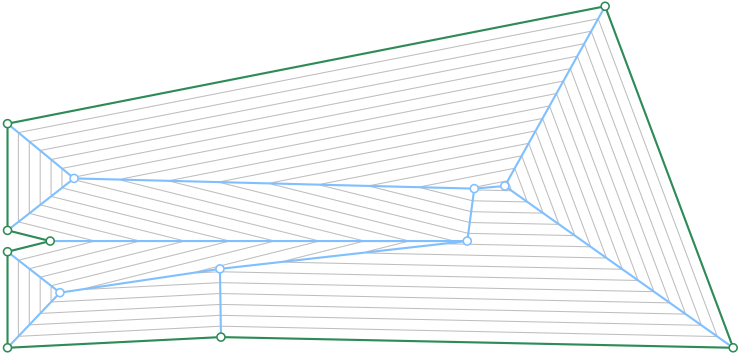
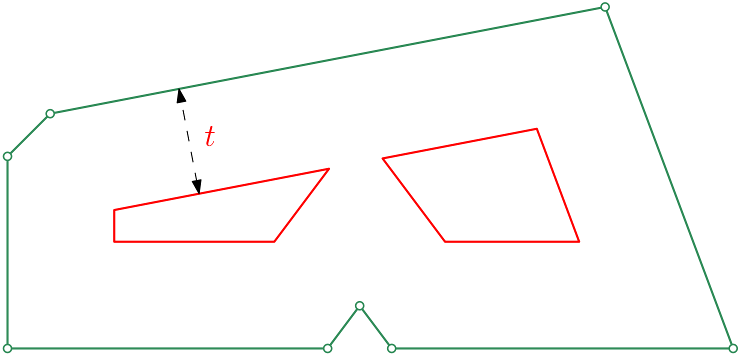


Offsetting

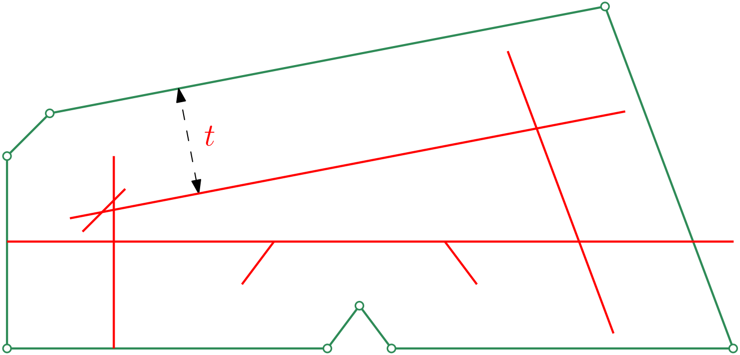
- How can we determine all offsets that correspond to some user-specified offset distance t?



Offsetting

Standard approach

1. Compute an elementary offset segment for each input segment.



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1. Compute an elementary offset segment for each input segment.
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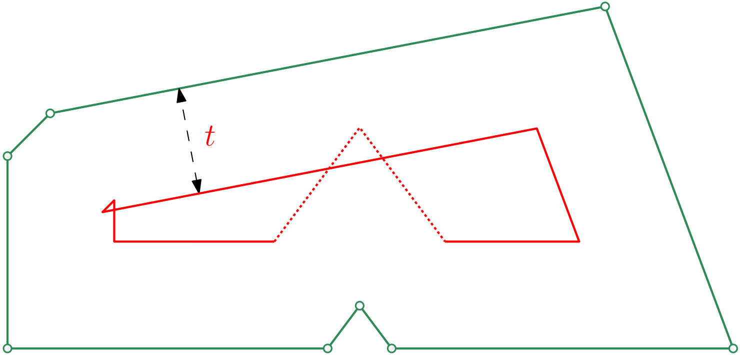

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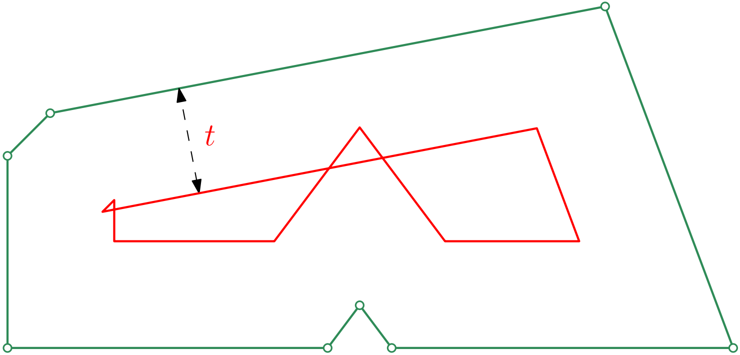
Standard approach

1. Compute an elementary offset segment for each input segment.
2. Trim at intersections of neighboring segments, and close gaps to form one loop.



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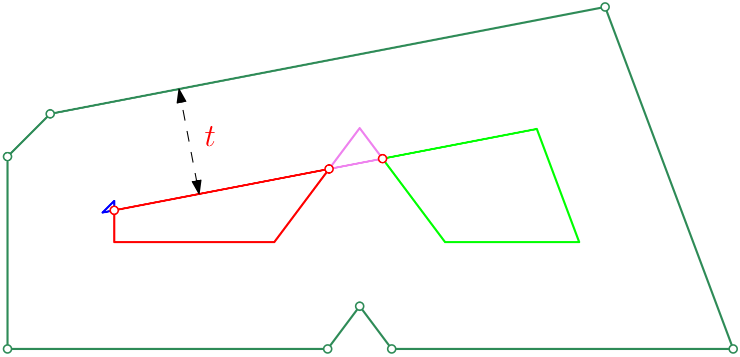

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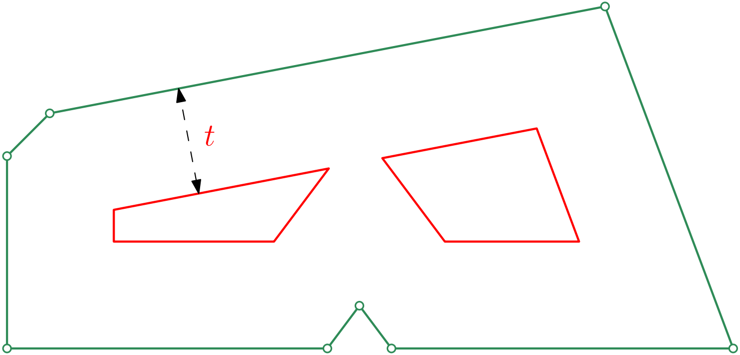
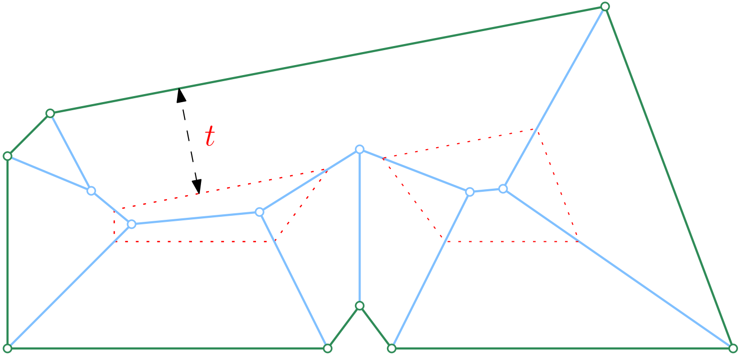


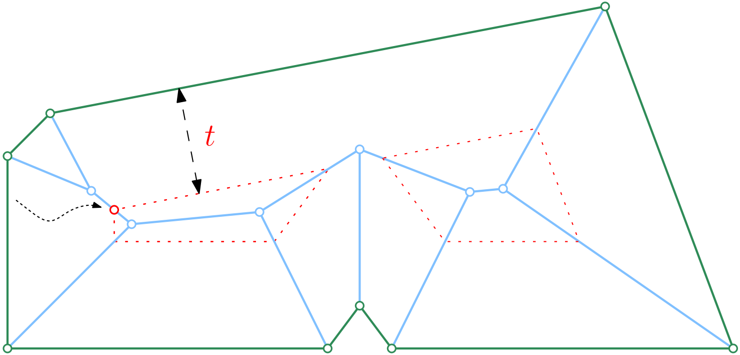
Offsetting Based on Straight Skeleton



Offsetting Based on Straight Skeleton

Scan straight skeleton

1. Choose SK edge not yet intersected by an offset loop; compute start vertex.



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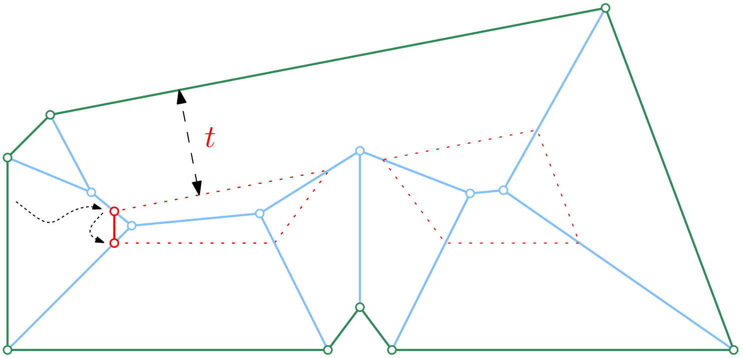
Scan straight skeleton

1. Choose SK edge not yet intersected by an offset loop; compute start vertex.
2. Advance clockwise along boundary of SK face and compute next vertex.



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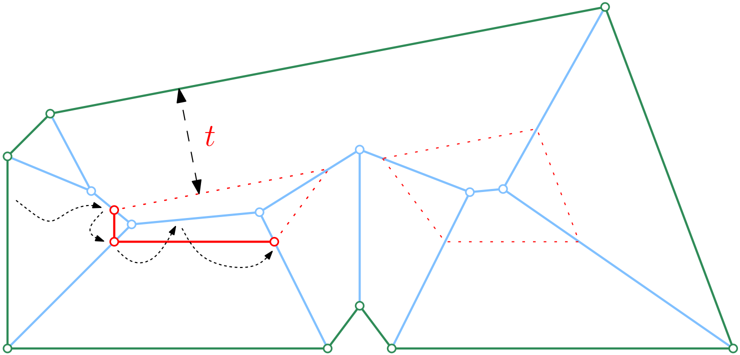

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1. Choose SK edge not yet intersected by an offset loop; compute start vertex.
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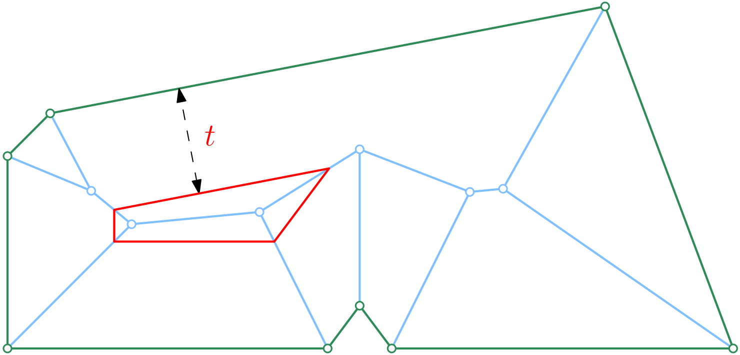
4. Finish one offset curve.



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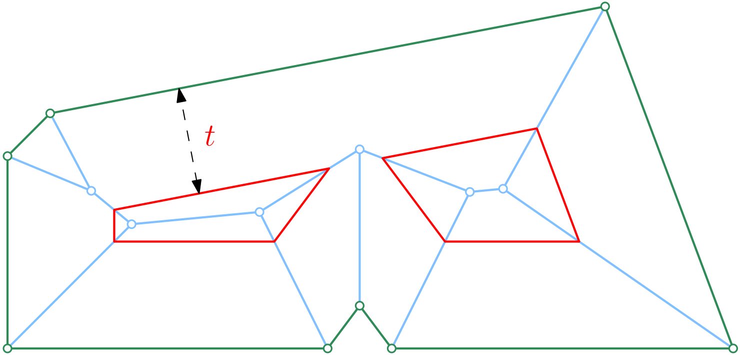
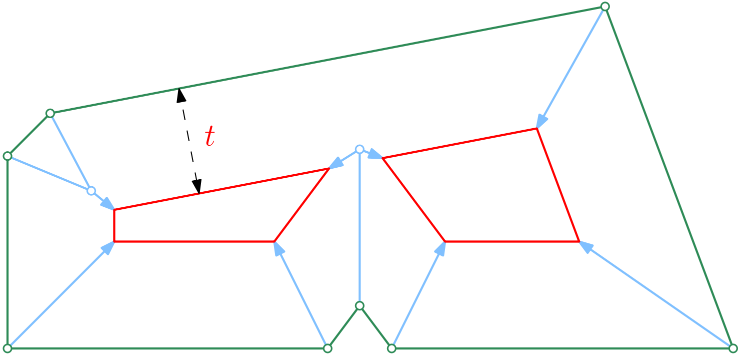
4. Finish one offset curve. Continue with next offset curve.



Offsetting Based on Straight Skeleton

Alternative: Halt wavefront

Halt wavefront-propagation when the offset distance t is reached.



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SURFER

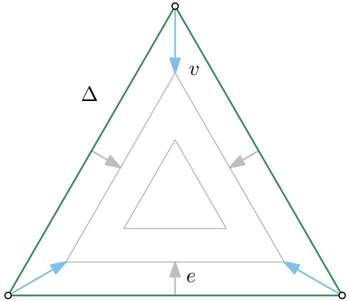
Straight-skeleton algorithm, based on kinetic triangulations, implemented in C and named SURFER.

UNIVERSITÄT SALZBURG
Computational Geometry and Applications Lab

Implementation: Finding and Classifying Collapse Times

Different ways to compute collapse time

Suppose that the three vertices of a triangle move towards one point.



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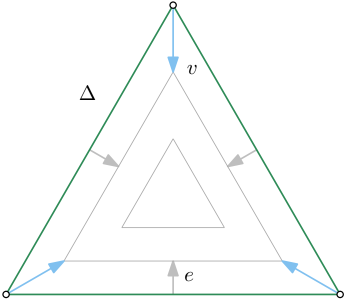

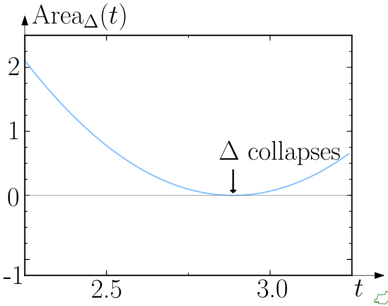

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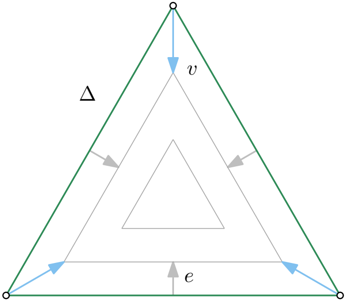

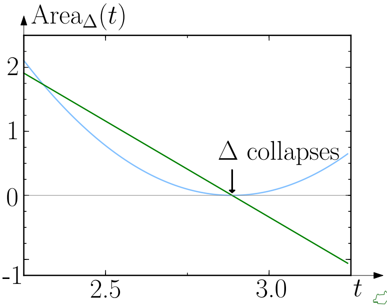

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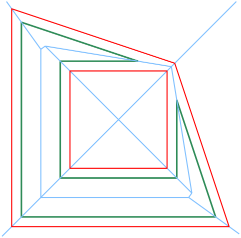

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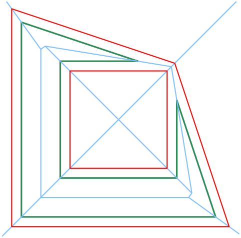

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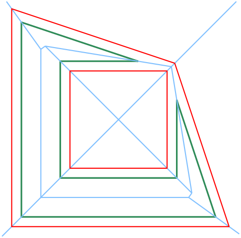

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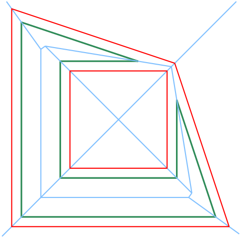
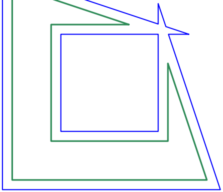
- CLIPPER and GEOS: Polygon-clipping libraries that apply general-purpose Boolean clipping algorithms to compute offsets.





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Computation of one offset

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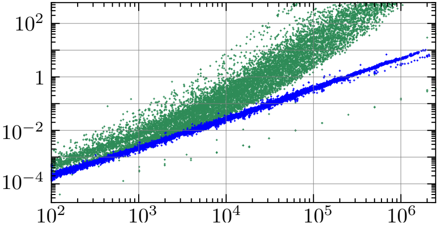

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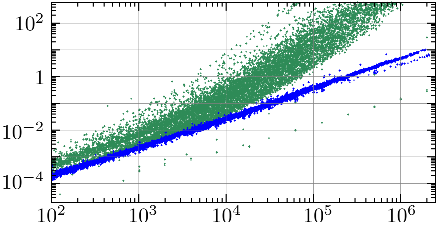
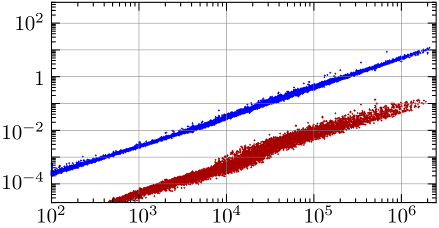


SK and SK-based offsetting

- Full SK by SURFER,
- One offset based on SK.



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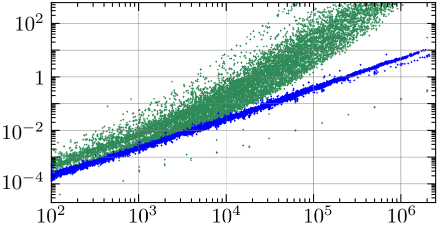

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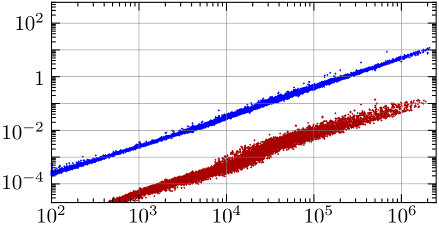
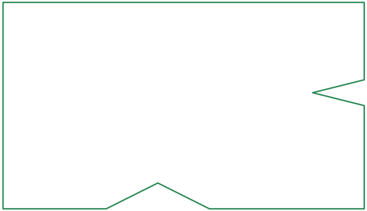


Experimental result

SURFER consumes roughly $5.8 \cdot 10^{-7} n \log n$ microseconds for an *n*-segment input. Except for a few convex polygons, a full run of SURFER is always (substantially) faster than the computation of one offset by CLIPPER.

Comparison of Sample Offsets



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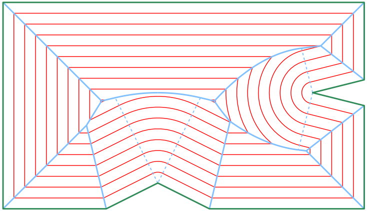

Voronoi diagram and rounded offsets

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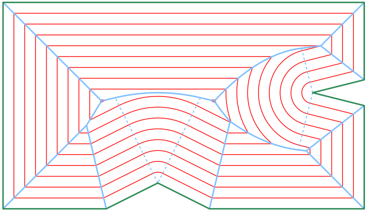

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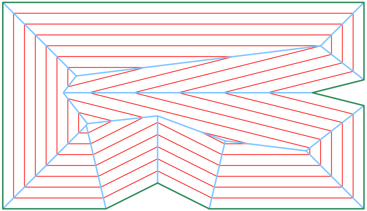

Straight skeleton and mitered offsets

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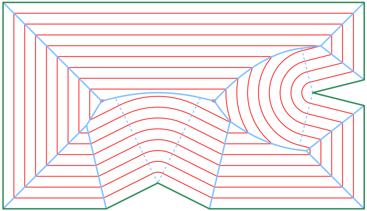

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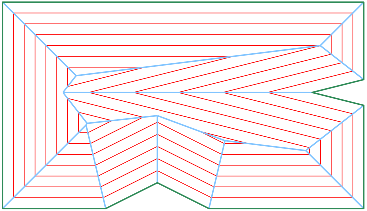

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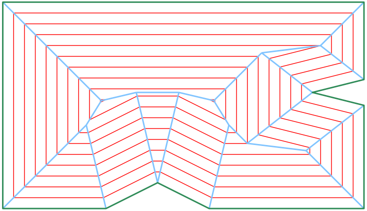

Straight skeleton and beveled offsets

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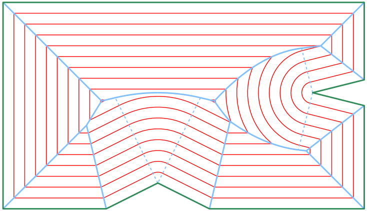

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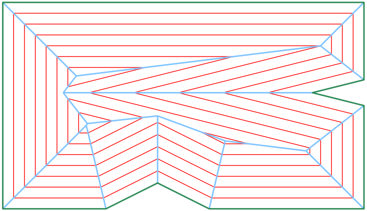
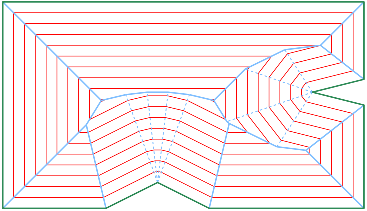
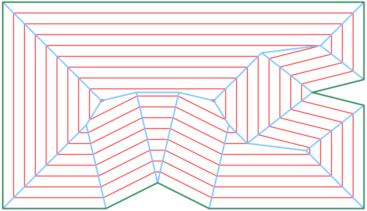


Straight skeleton and mitered offsets

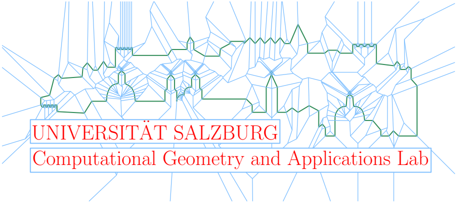


Linear axis and multi-segment bevels



Straight skeleton and beveled offsets

Gallery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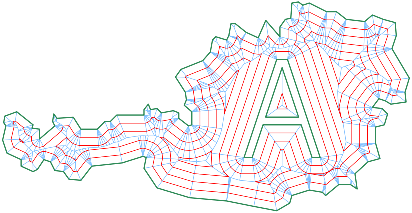

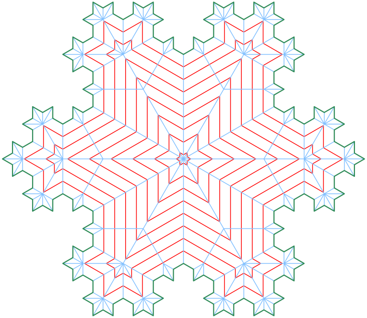

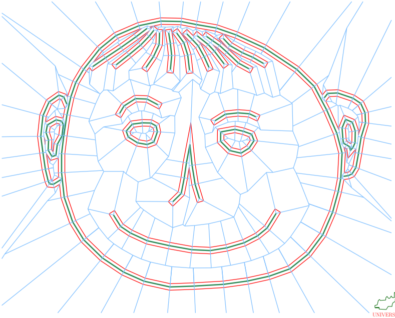

Thanks for Your Attention — Questions Welcome!

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