Computation and Recognition of Weighted Skeletal Structures in the Plane

Dissertation Defense

Günther Eder

UNIVERSITÄT SALZBURG

UNIVERSITY OF SALZBURG
Computational Geometry and Applications Lab

Introduction

- Min-/Max-Volume Roofs of Polygonal Footprints of Buildings
- Straight Skeleton of an Orthogonal Monotone Polygon
- Positively Weighted Straight Skeletons of Simple Polygons
- Recognizing Geometric Trees as Weighted Straight Skeletons
- Multiplicatively Weighted Voronoi Diagrams in the Maximum Norm

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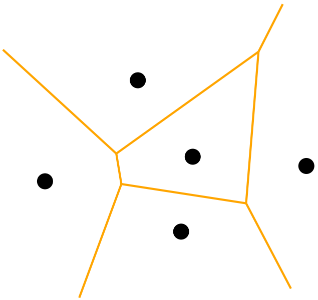
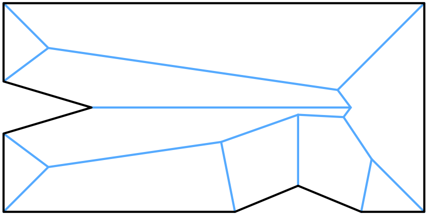
Voronoi Diagram



Straight Skeleton



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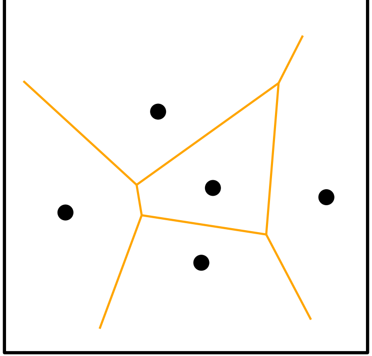

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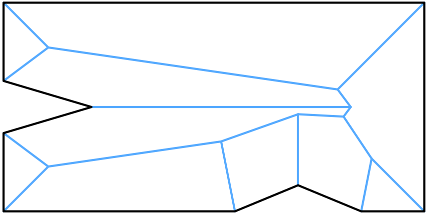

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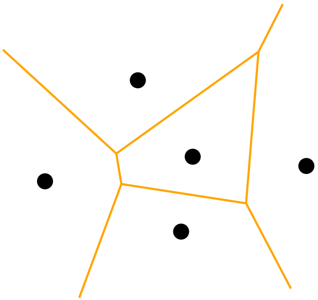
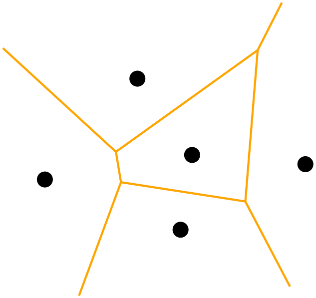


- Definition

Voronoi Diagram



- Definition
- Applications

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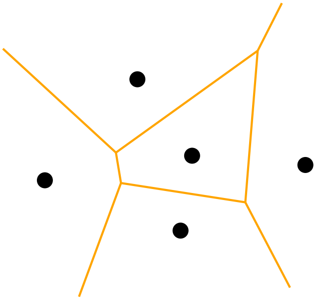
Voronoi Diagram



- Definition
- Applications
- Our Result

Voronoi Diagram – Definition

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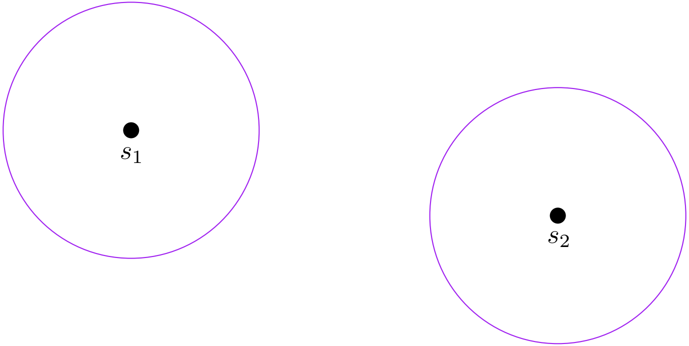

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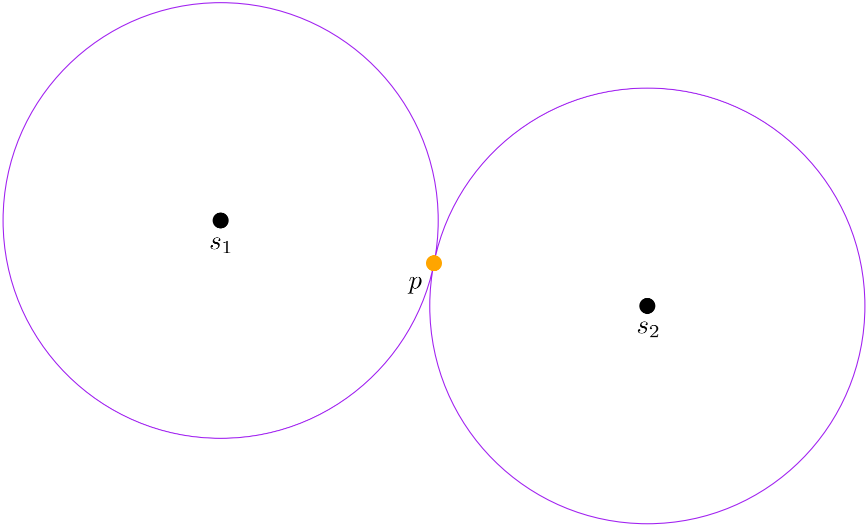

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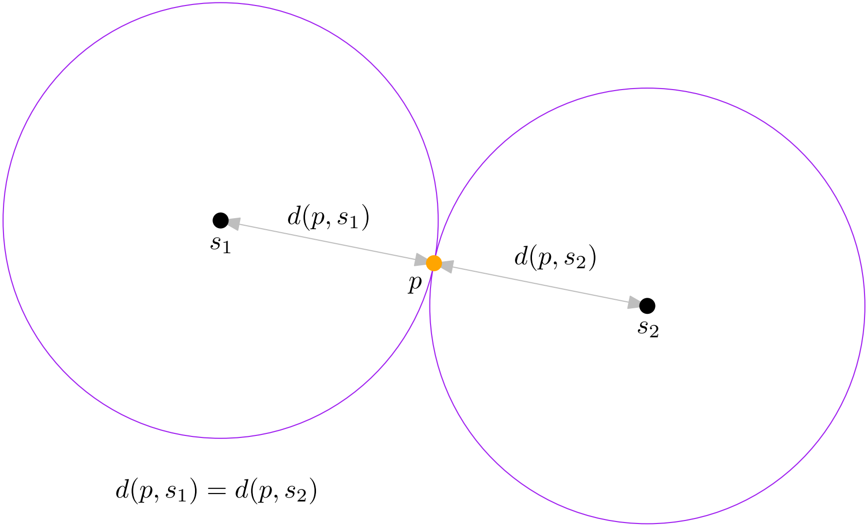

$$d(p, s_1) = d(p, s_2)$$

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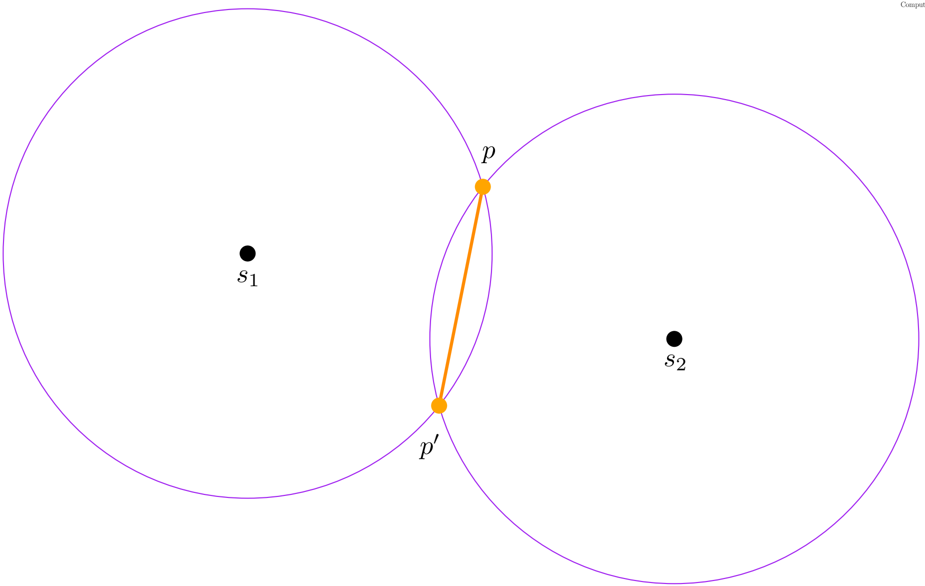

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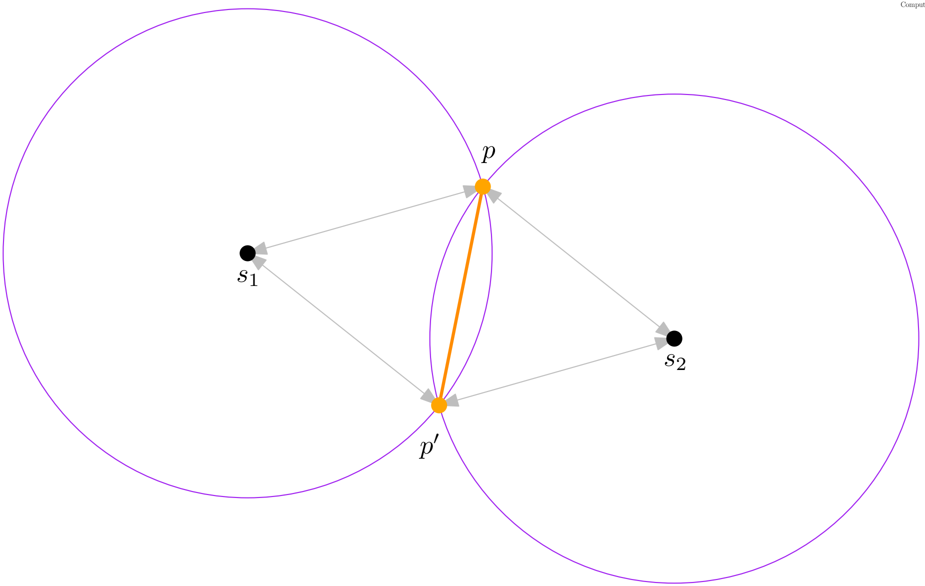

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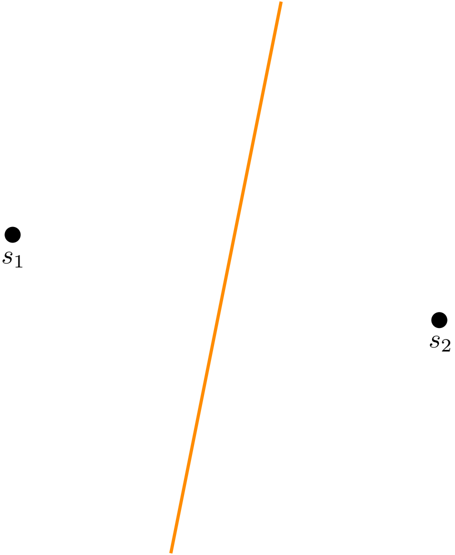

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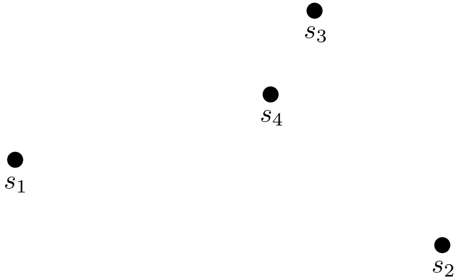

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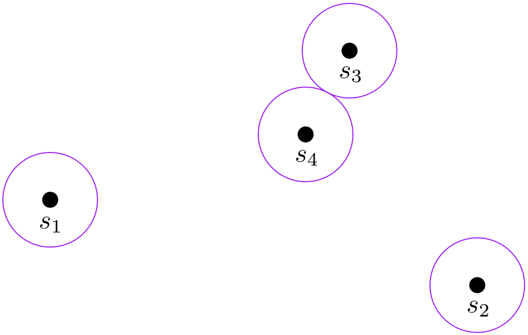

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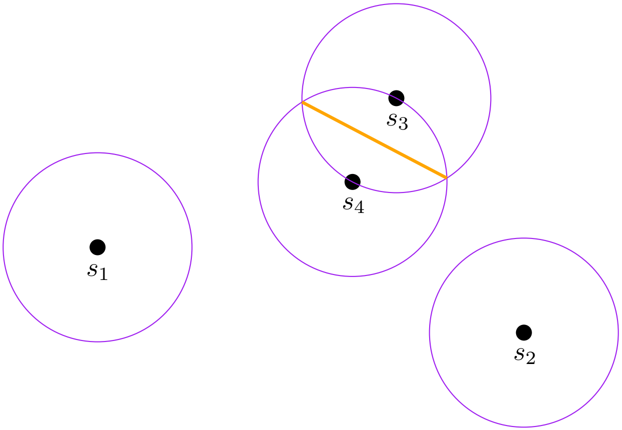

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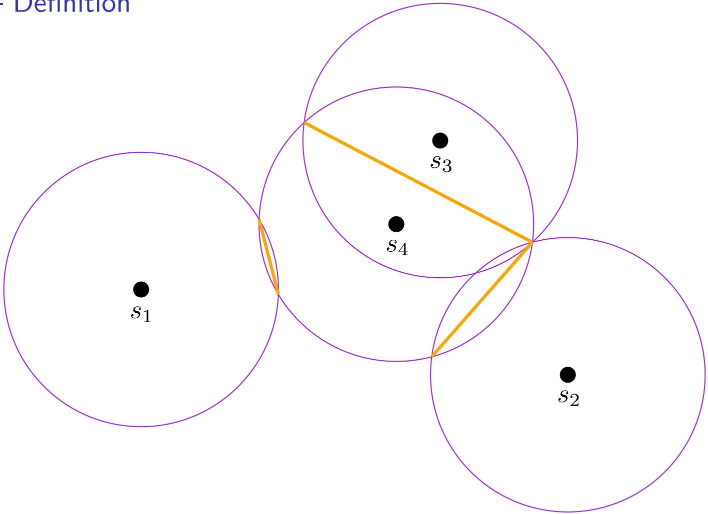

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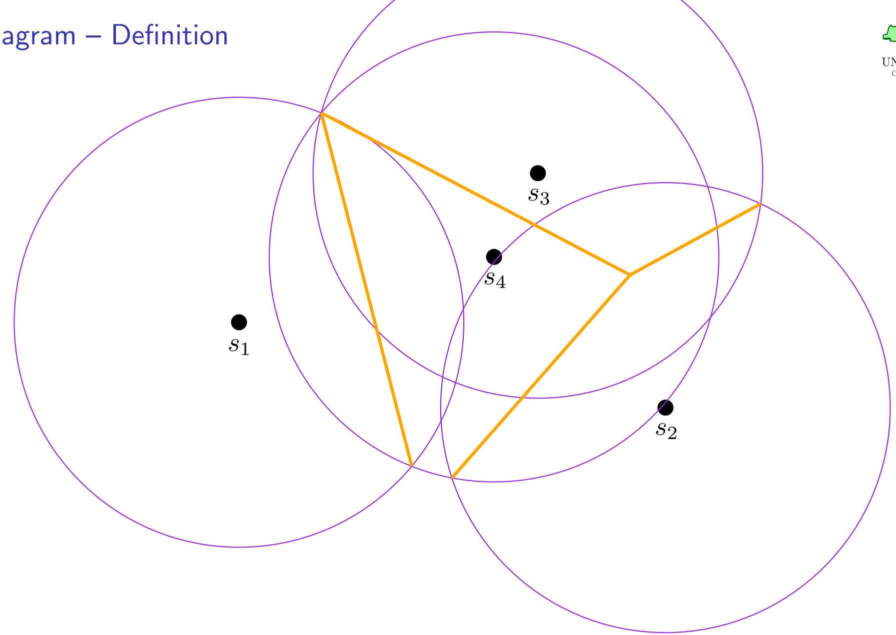

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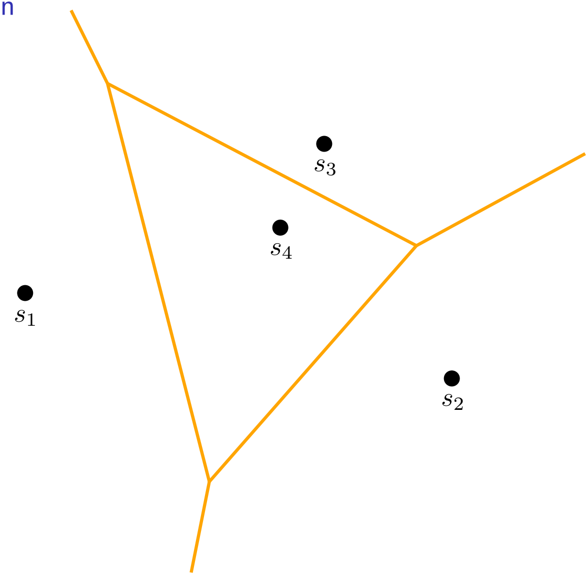

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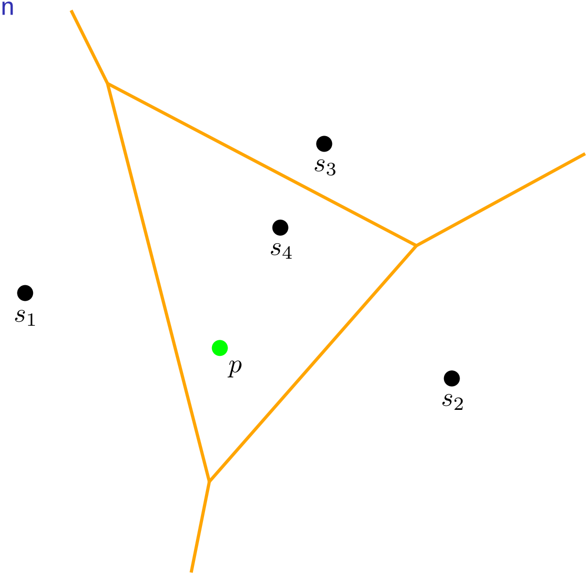

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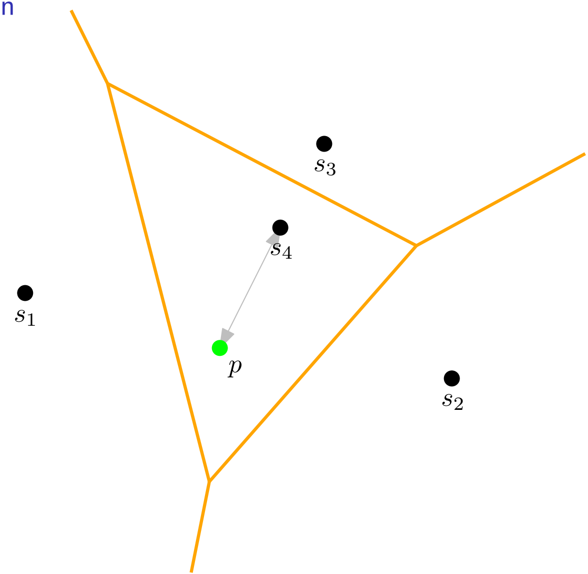

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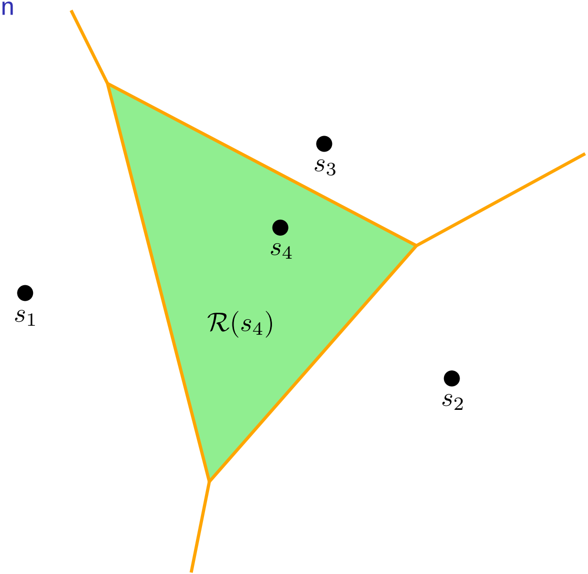

Voronoi Diagram – Applications

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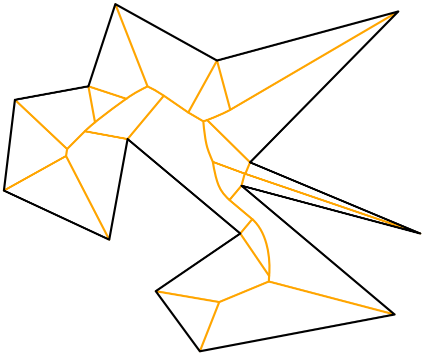
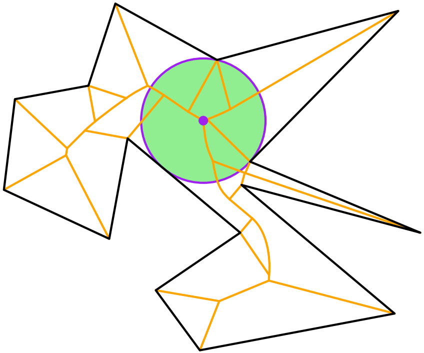


Maximum-Empty-Circle

Voronoi Diagram – Applications



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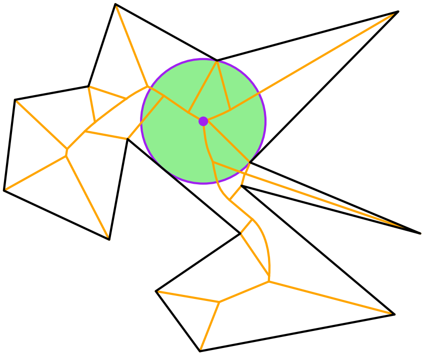

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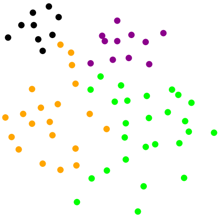
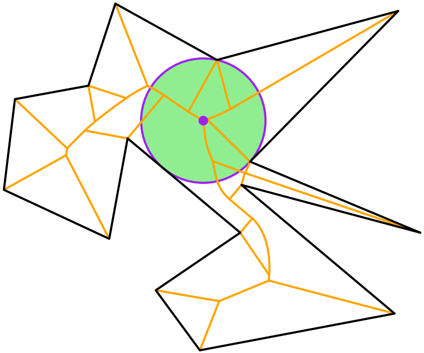


1-NN Classification

Voronoi Diagram – Applications



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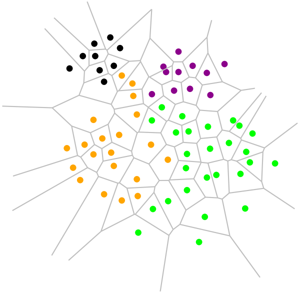

1-NN Classification

Voronoi Diagram – Applications

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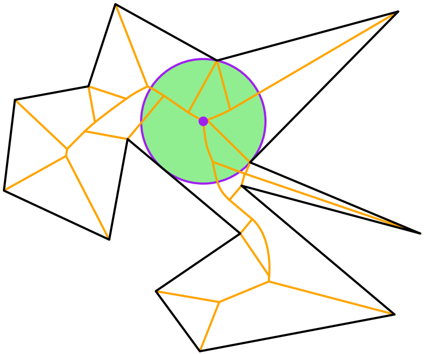

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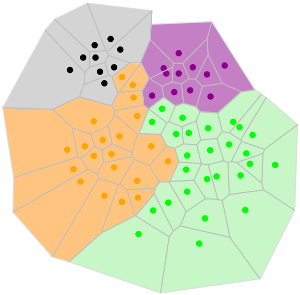

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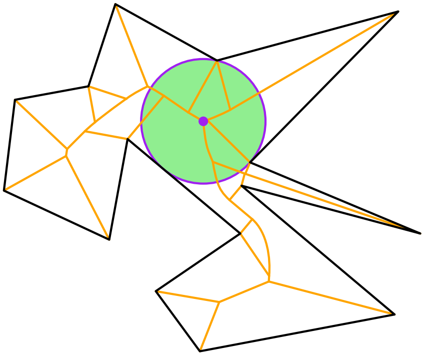

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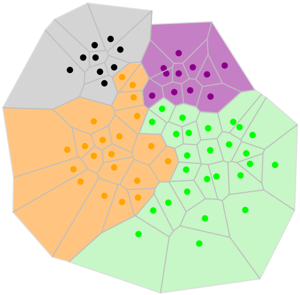

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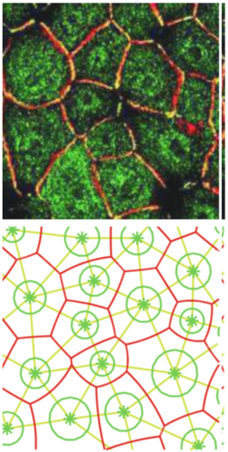
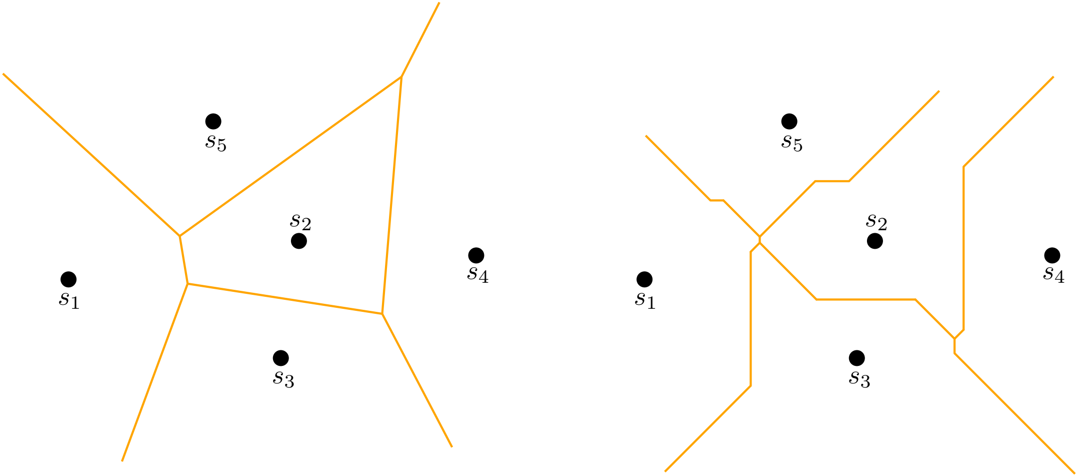


Cell Tissue Model
from Bock et al.[1]

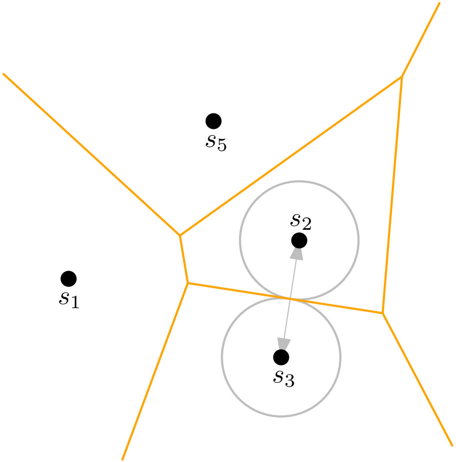
Voronoi Diagram – L_∞ & Weights



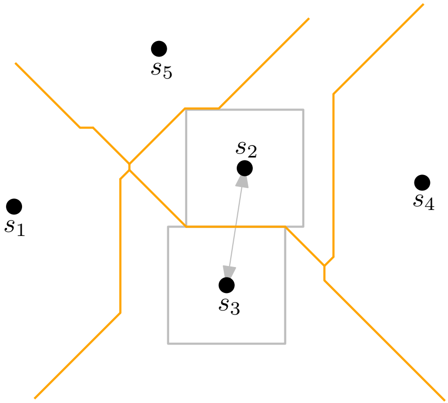
L_2-Norm

L_∞-Norm

Voronoi Diagram – L_∞ & Weights



L_2-Norm



L_∞-Norm

Voronoi Diagram – L_∞ & Weights

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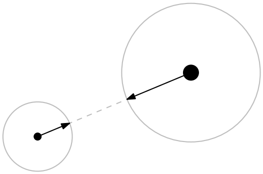

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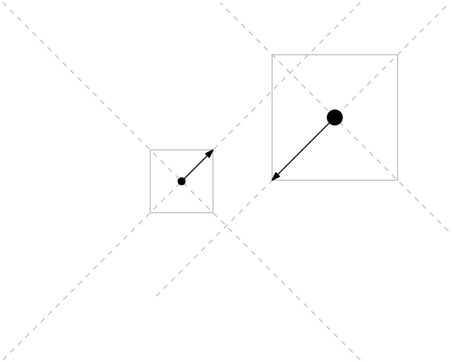

L_∞-Norm

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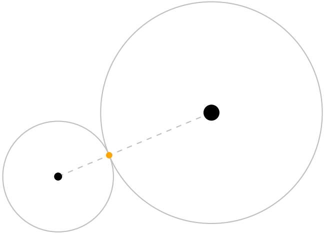

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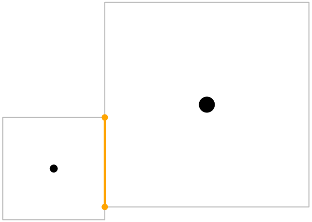

L_∞-Norm

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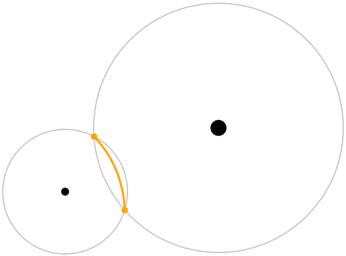

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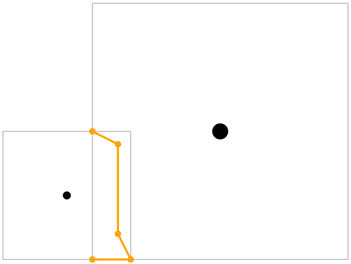

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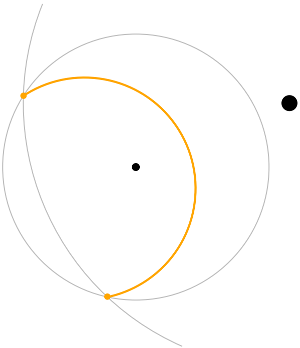

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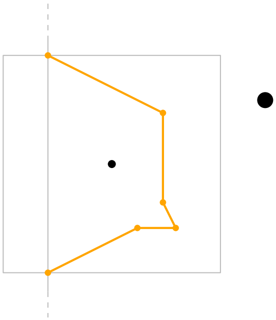

L_∞-Norm

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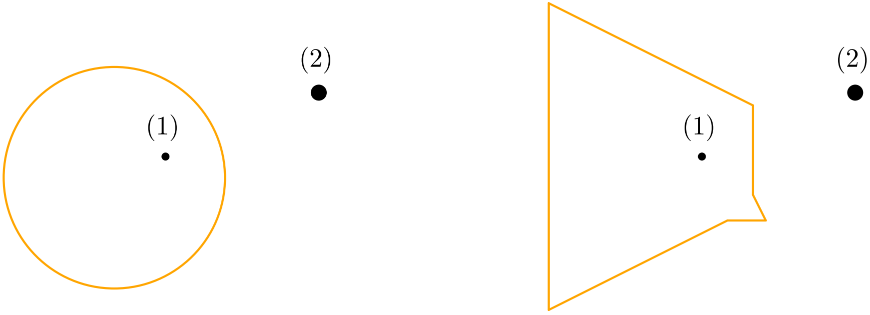

L_2-Norm $\qquad$ L_∞-Norm

Voronoi Diagram – Our Result

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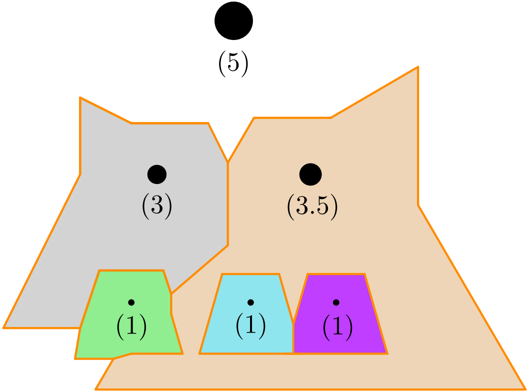
- Weighted Voronoi diagram in L_∞-norm.
  - Points, line-segments, and rectangles.
- $\Theta(n^2)$ combinatorial complexity bound.
- $\mathcal{O}(n^2 \log n)$ incremental construction algorithm.
  - Compute a single region.
  - Embed region in diagram of previous step.



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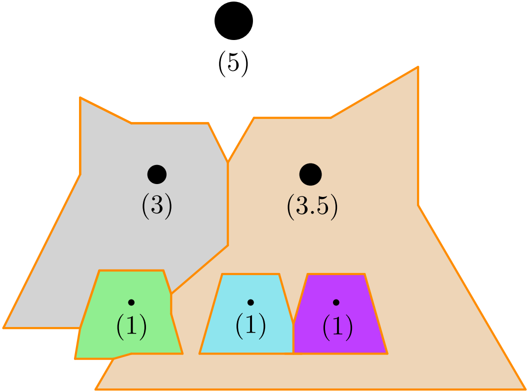

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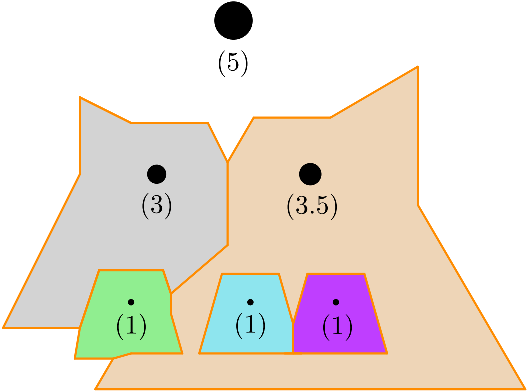

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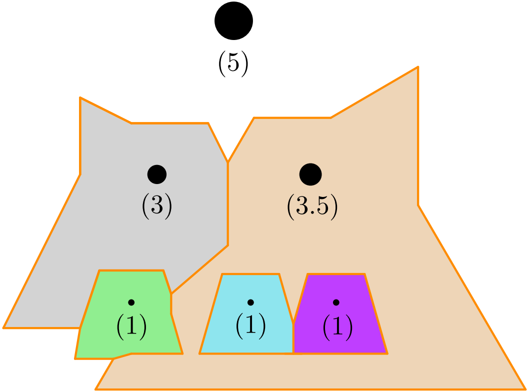

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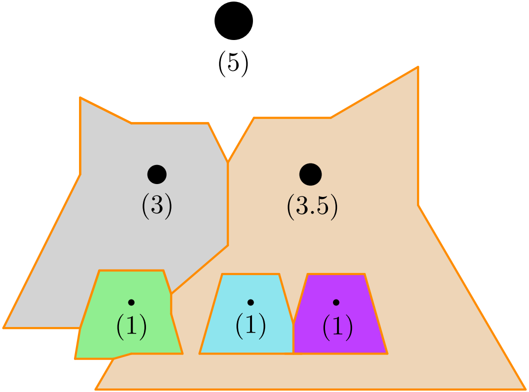

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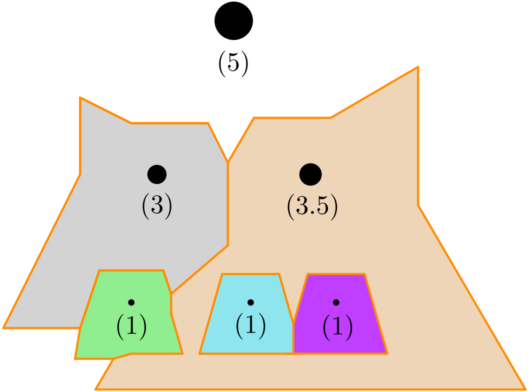
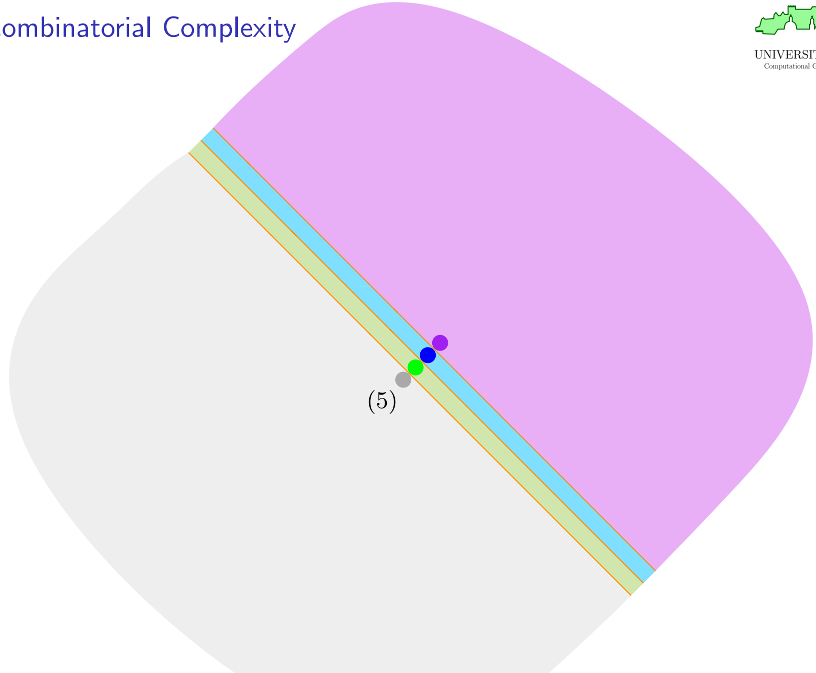


Voronoi Diagram – Combinatorial Complexity



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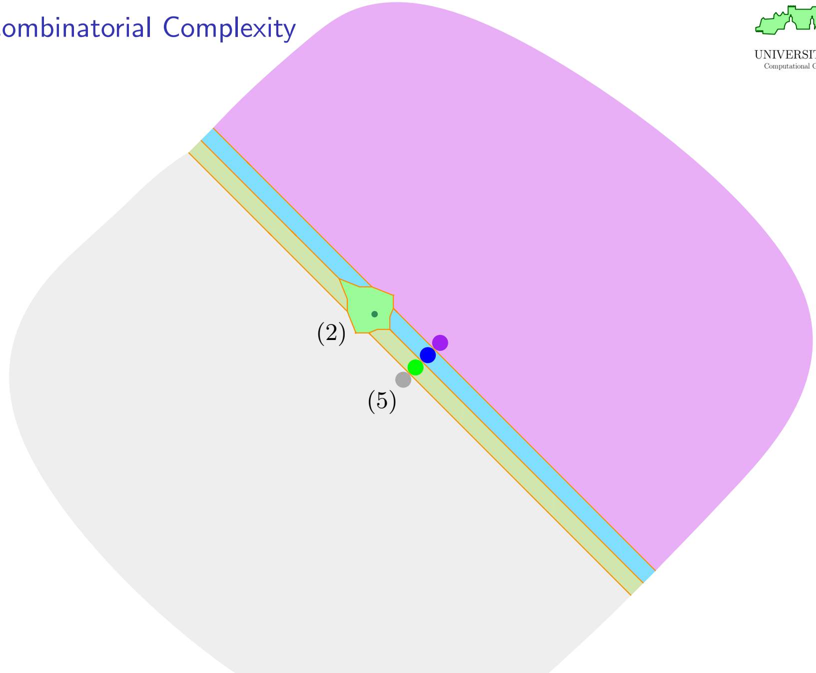

Voronoi Diagram – Combinatorial Complexity

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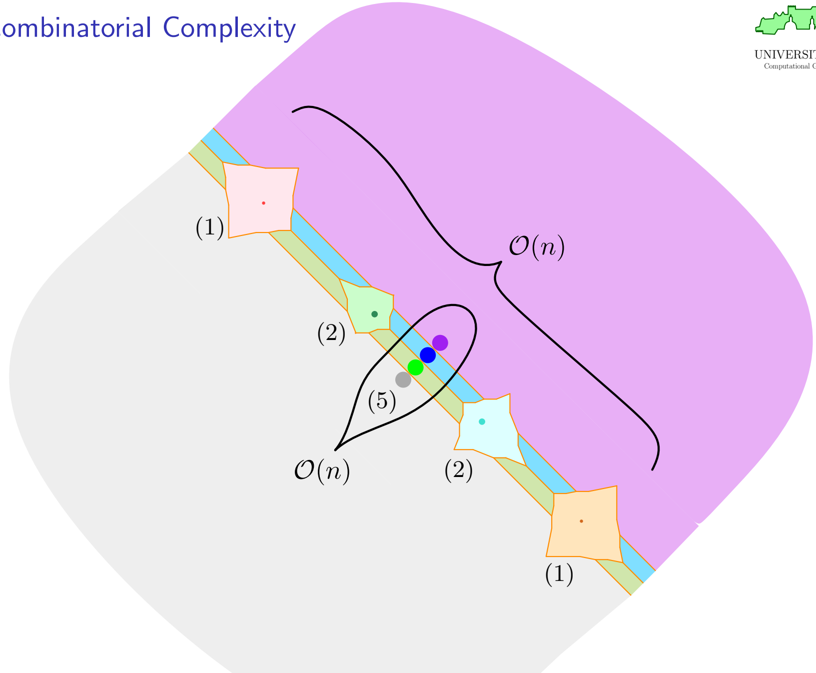

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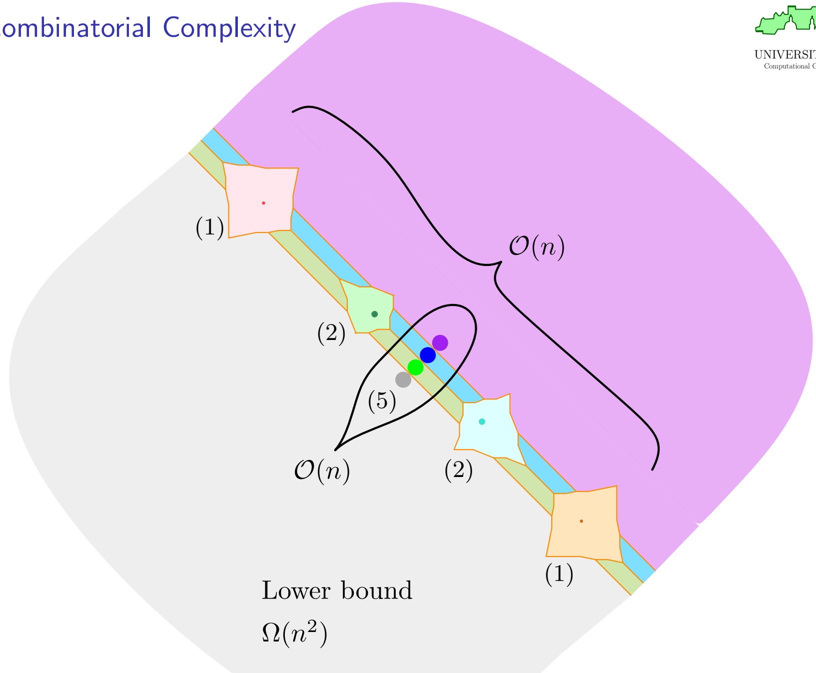

Voronoi Diagram – Incremental Construction

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Voronoi Diagram – Incremental Construction

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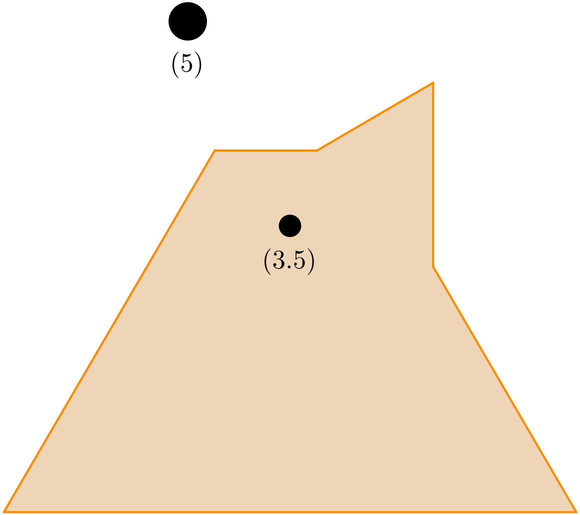
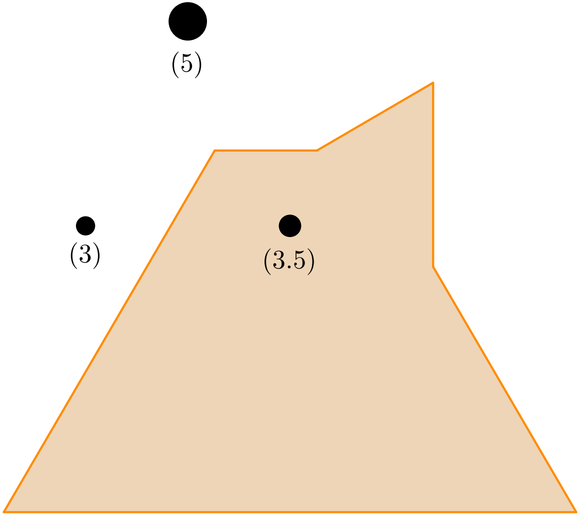


Voronoi Diagram – Incremental Construction



Voronoi Diagram – Incremental Construction

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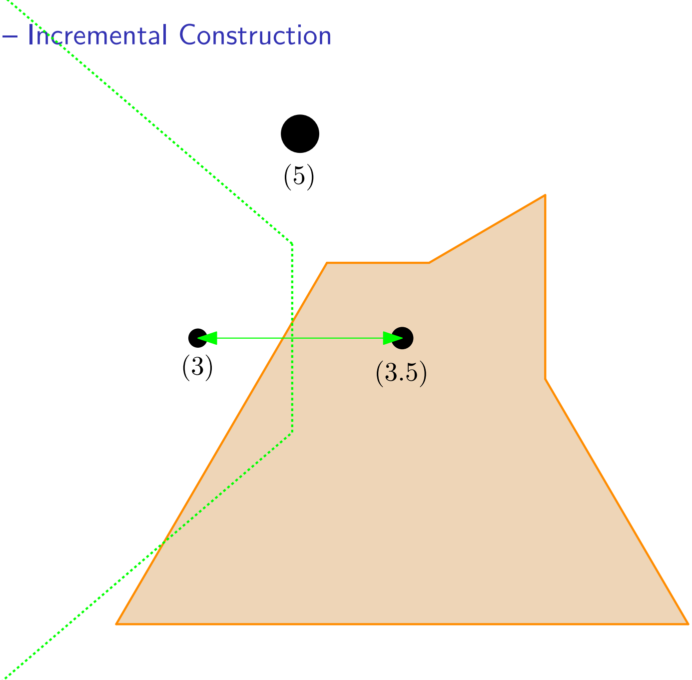

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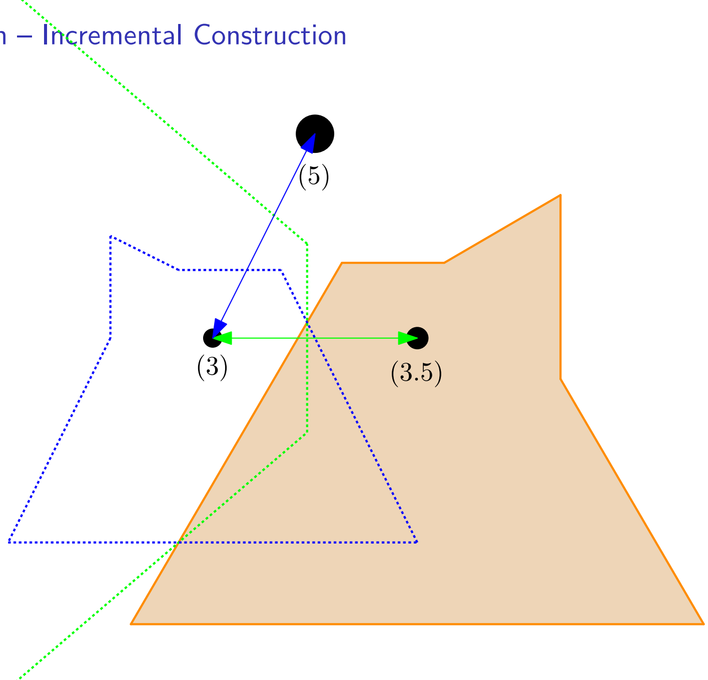

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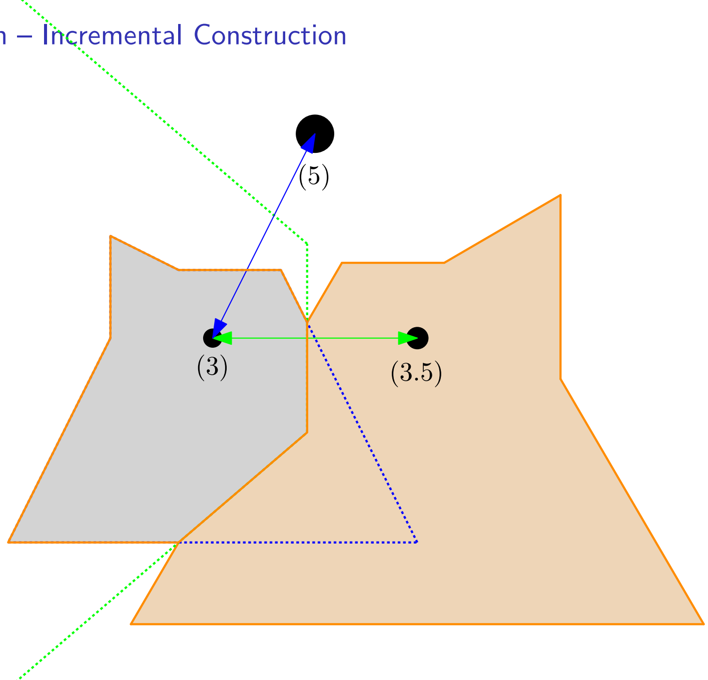

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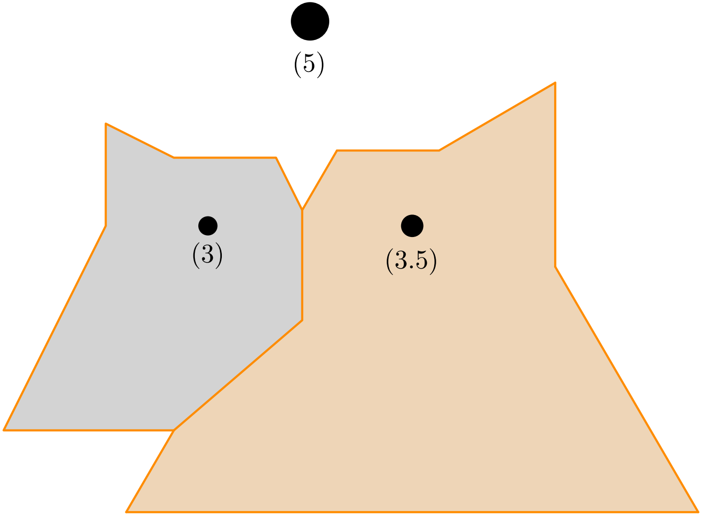

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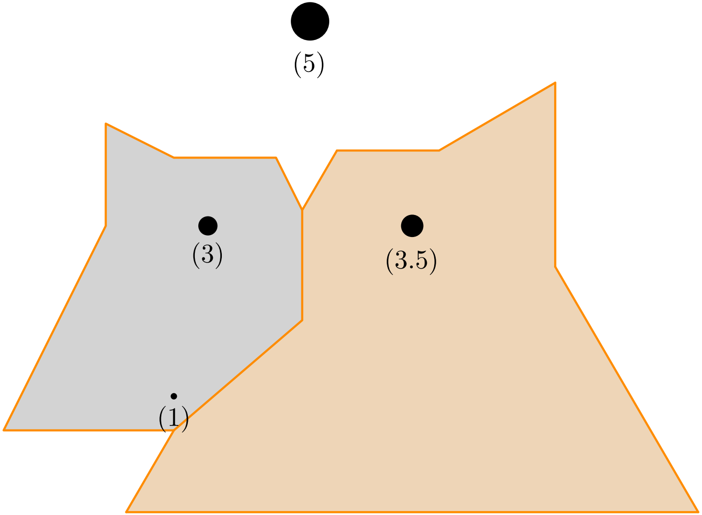

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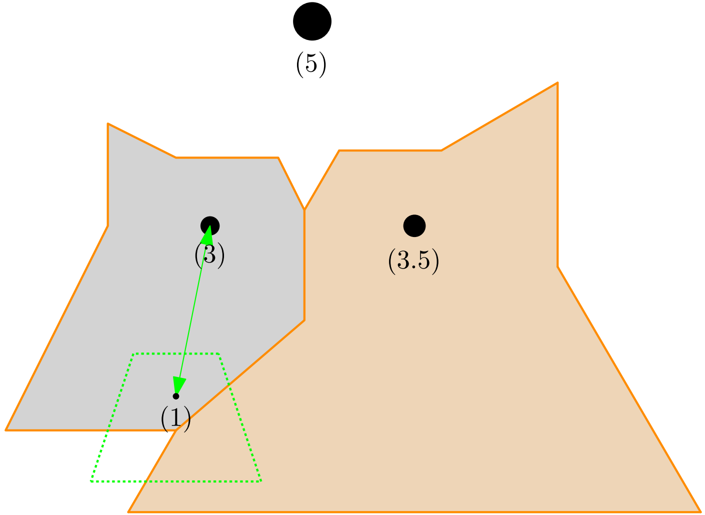

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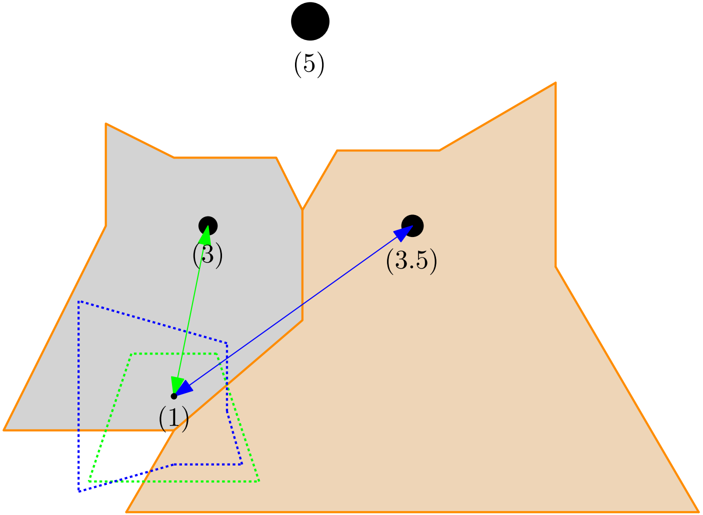

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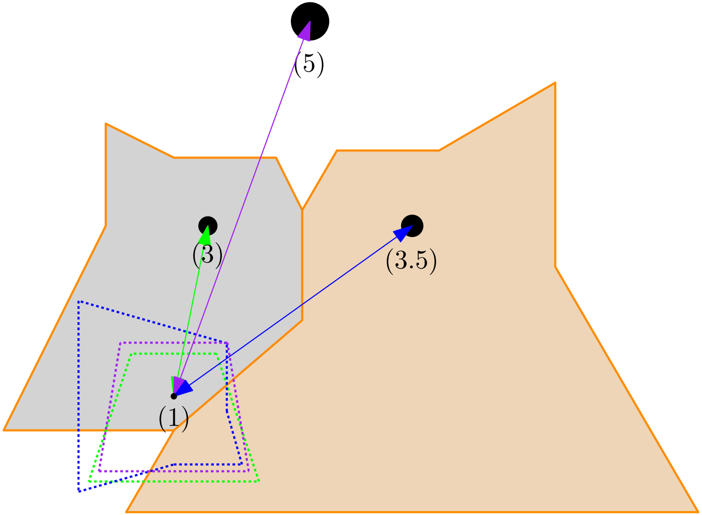

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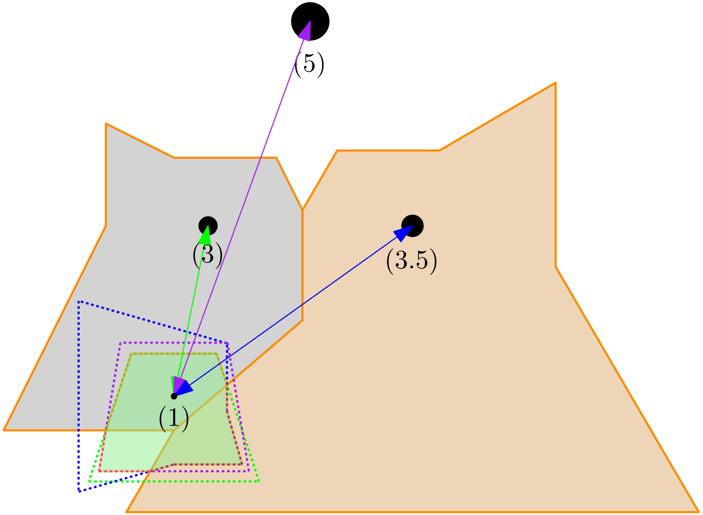

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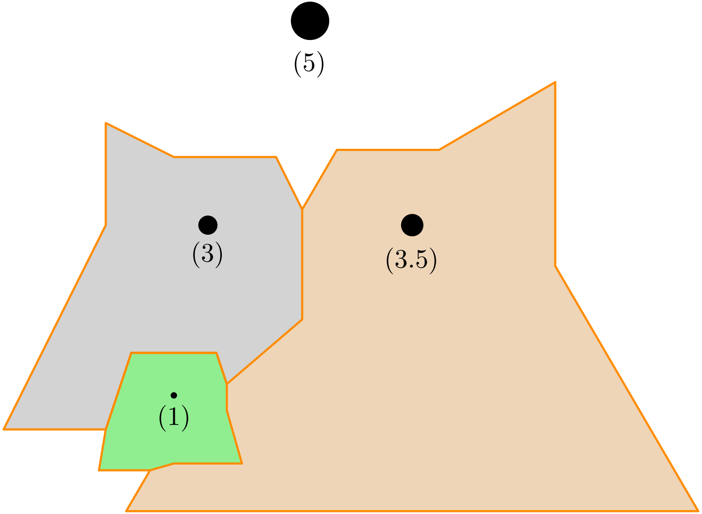

Voronoi Diagram – Incremental Construction

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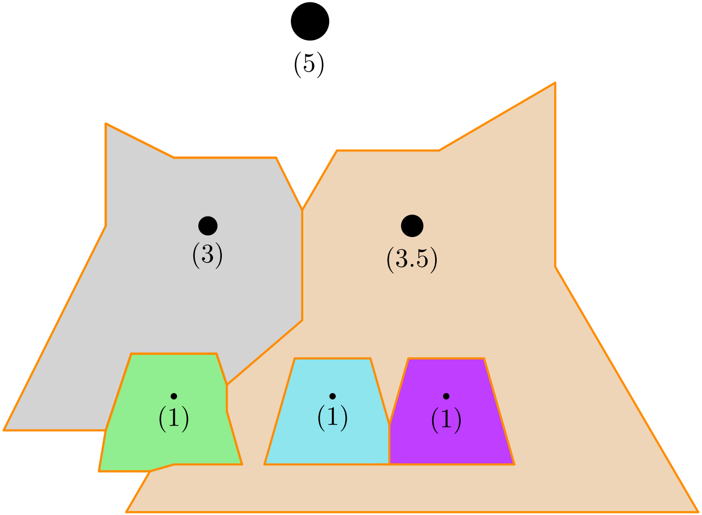

Voronoi Diagram – Summary

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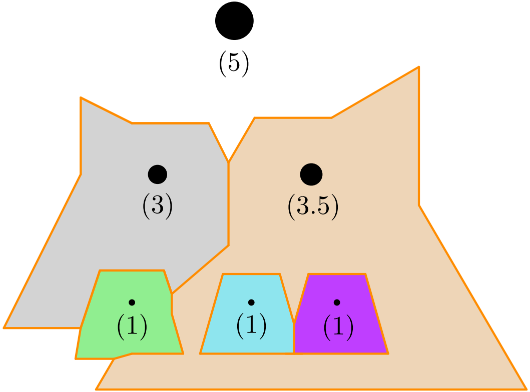
- Compute single region – $\mathcal{O}(n \log n)$
- Embed region in diagram – $\mathcal{O}(n \log n)$
- Overall $\mathcal{O}(n^2 \log n)$ time and $\mathcal{O}(n^2)$ space.



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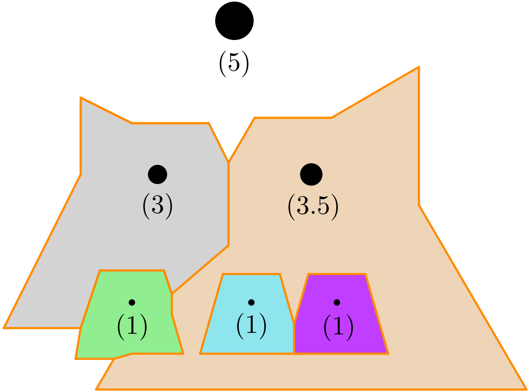

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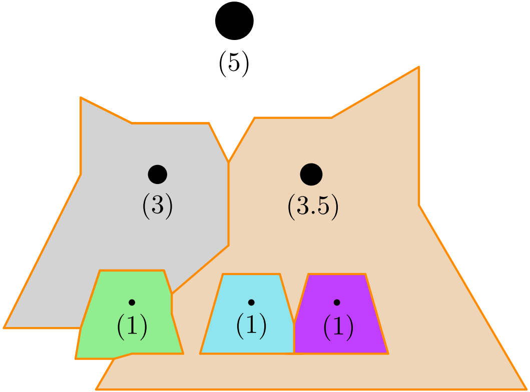
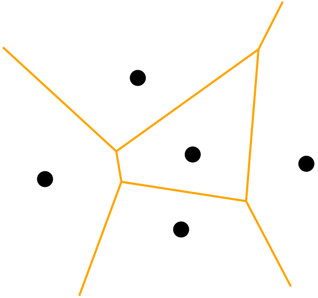
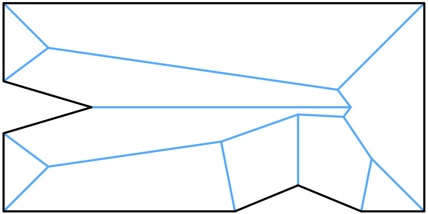


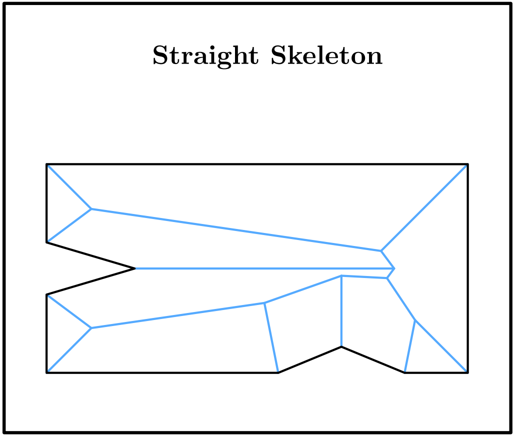
Voronoi Diagram



Straight Skeleton



- Definition
- Applications
- Our Result



Straight Skeleton – Definition

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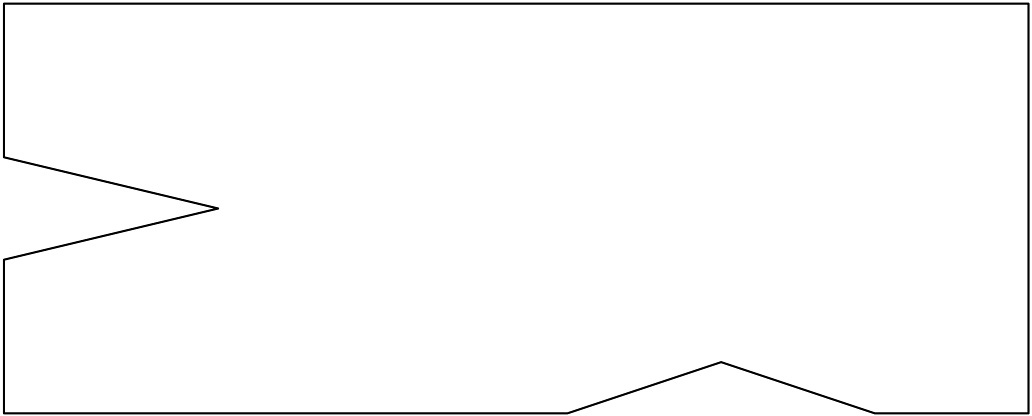

Straight Skeleton – Definition

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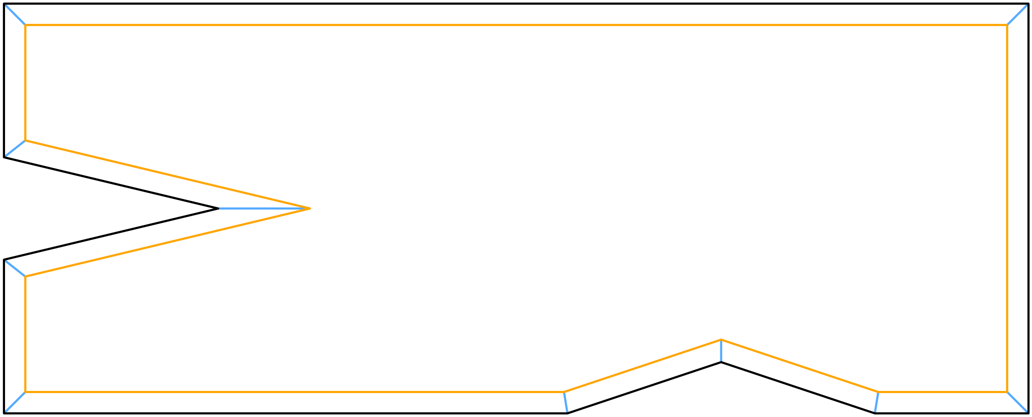

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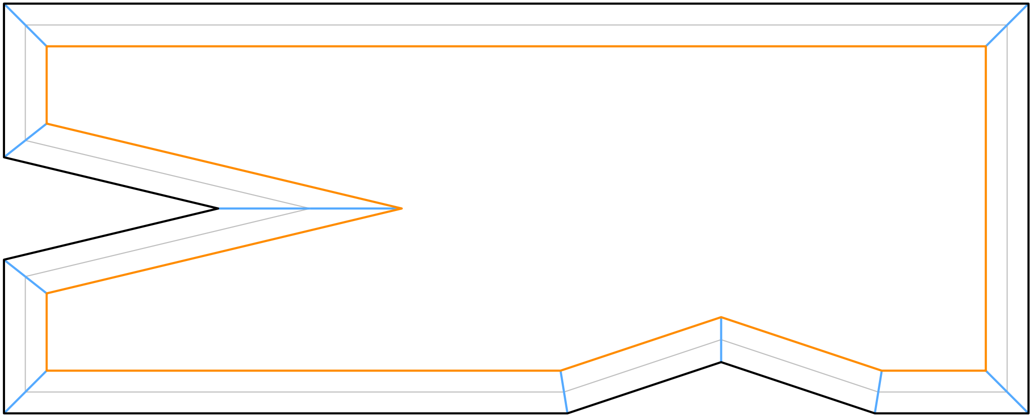

Straight Skeleton – Definition

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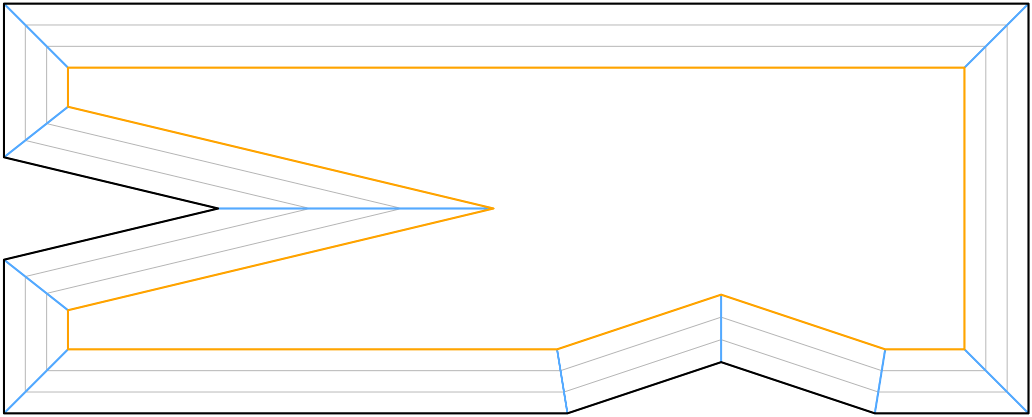

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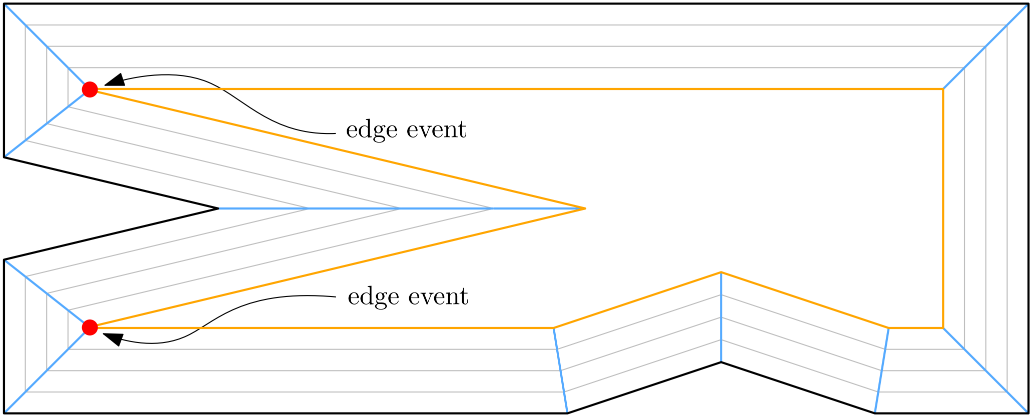

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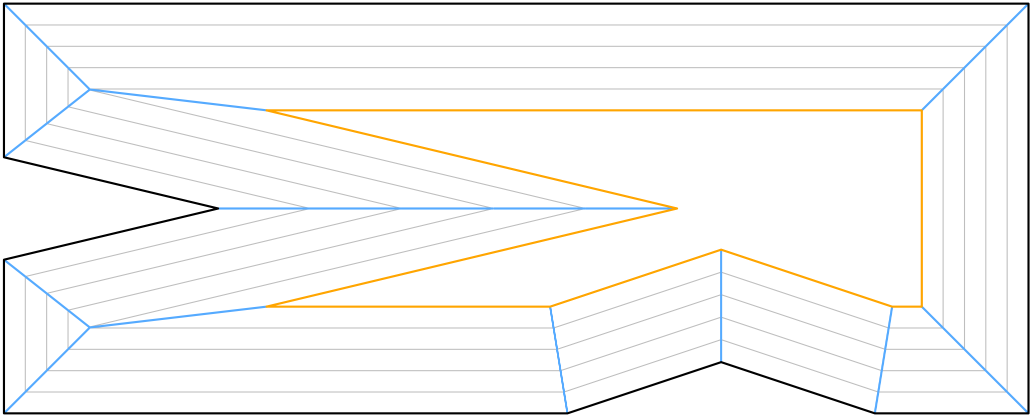

Straight Skeleton – Definition

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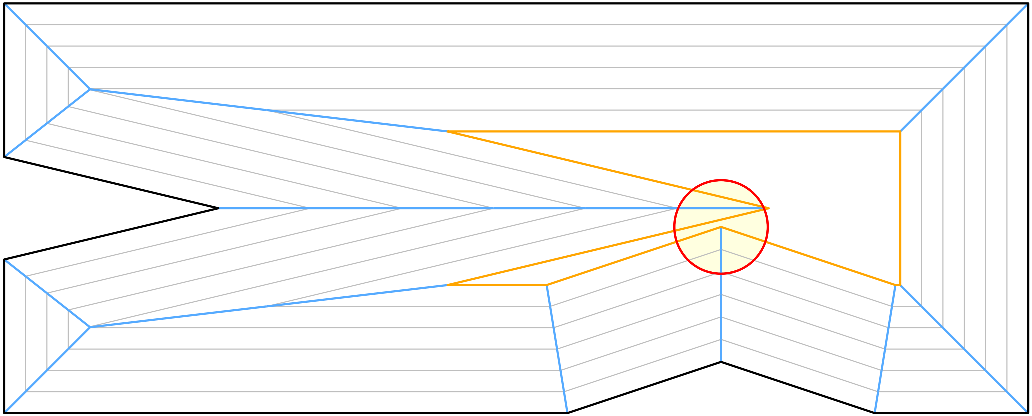

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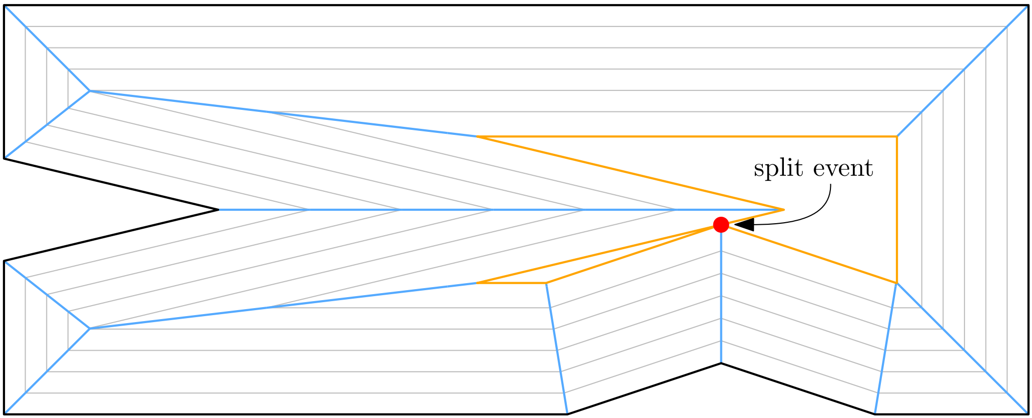

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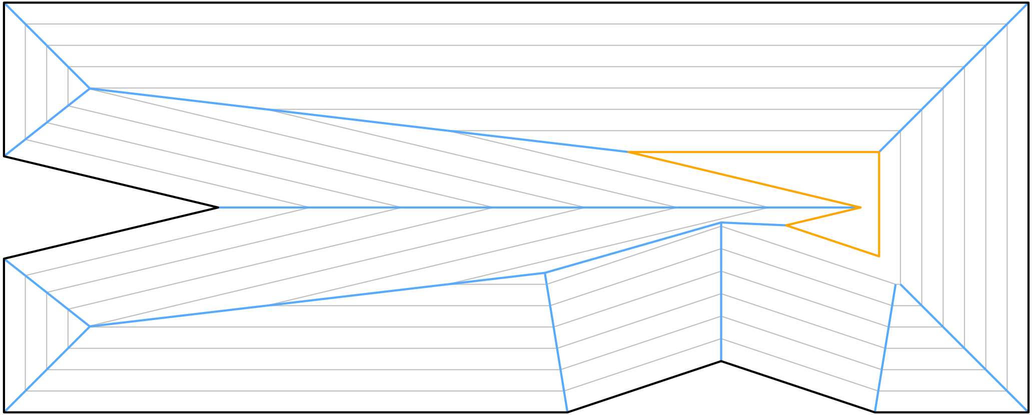

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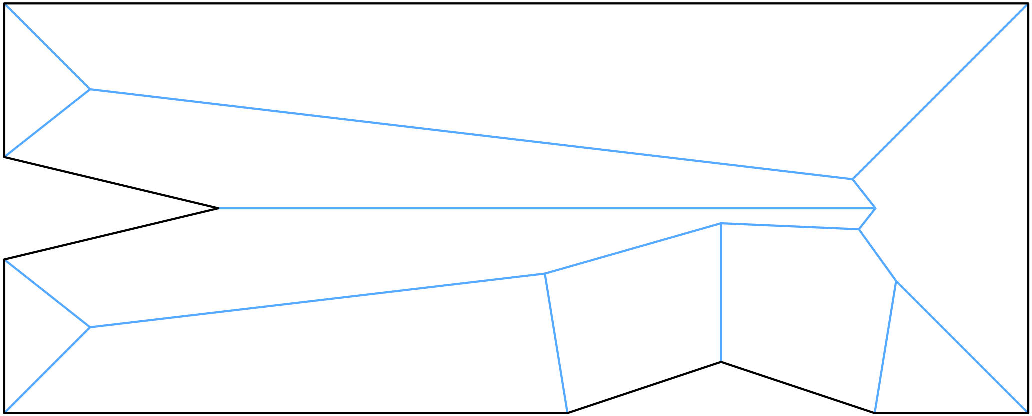

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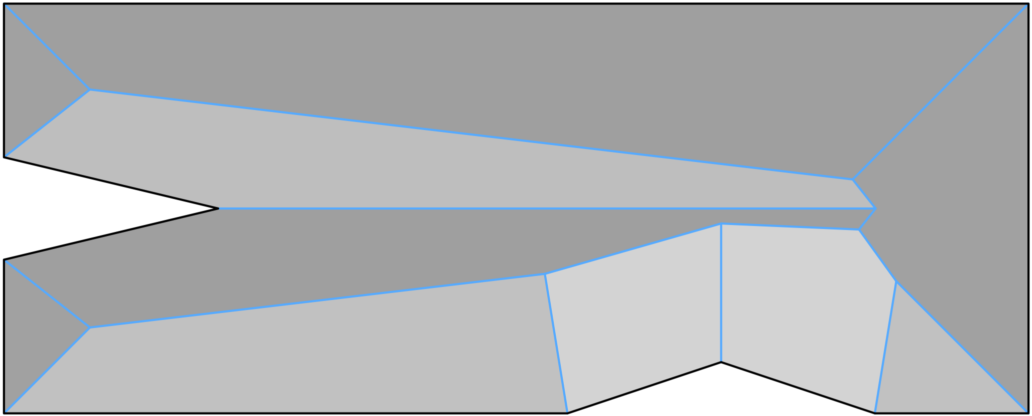

Straight Skeleton – Application: Polygon Offsetting

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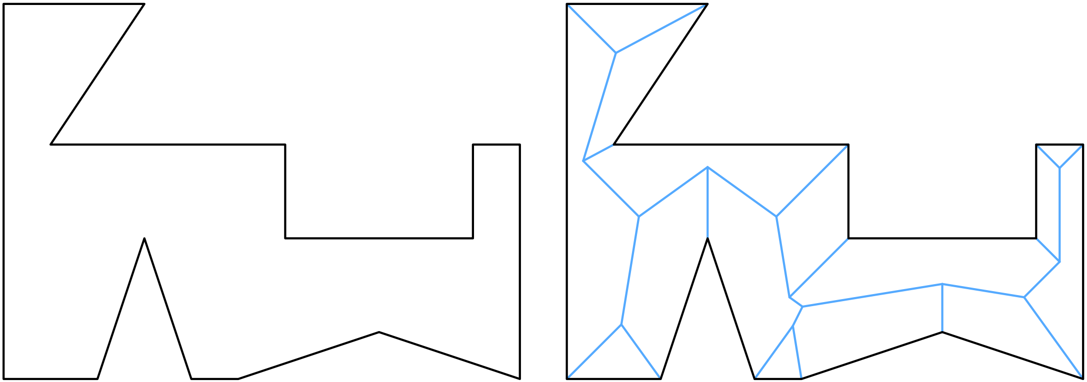

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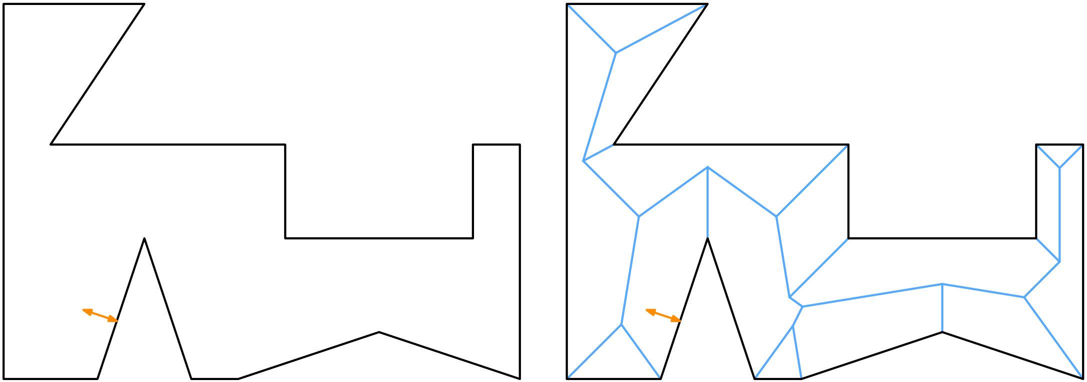

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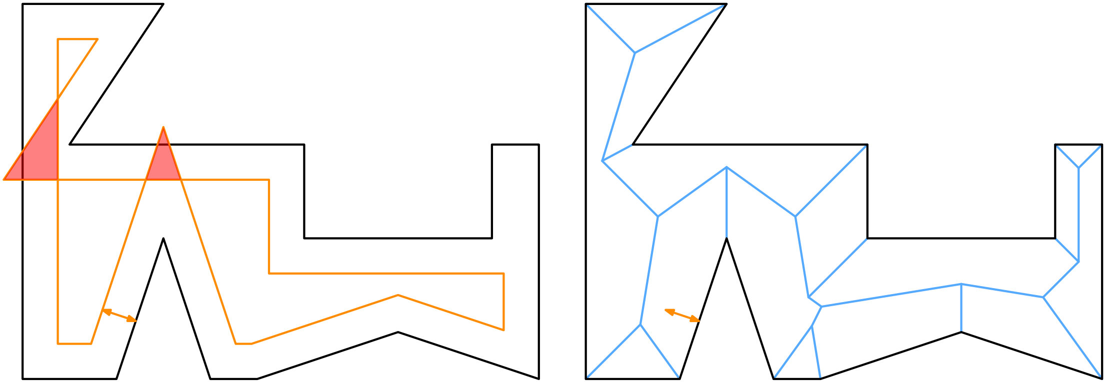

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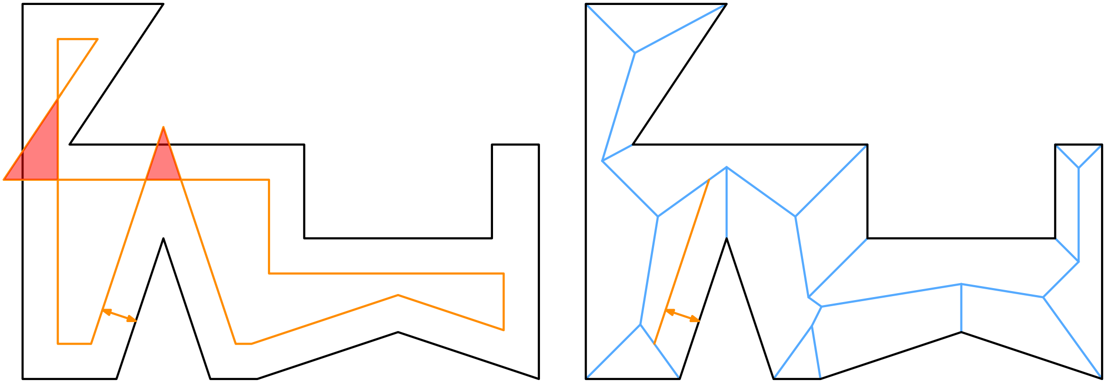

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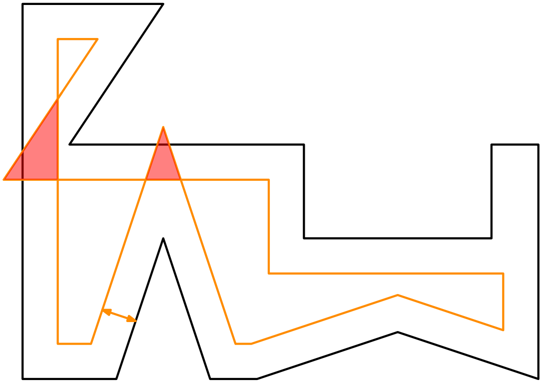

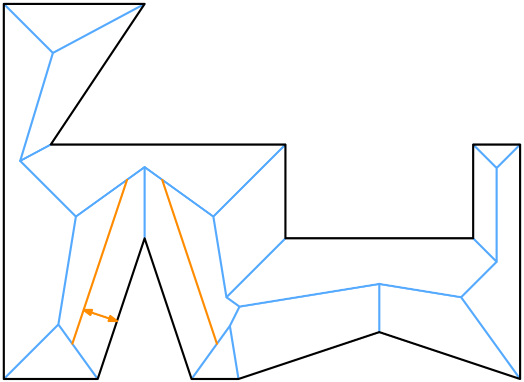

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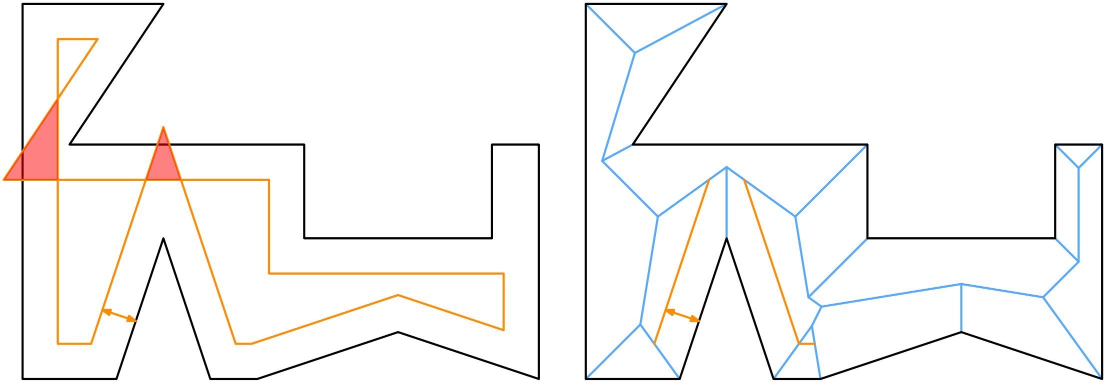

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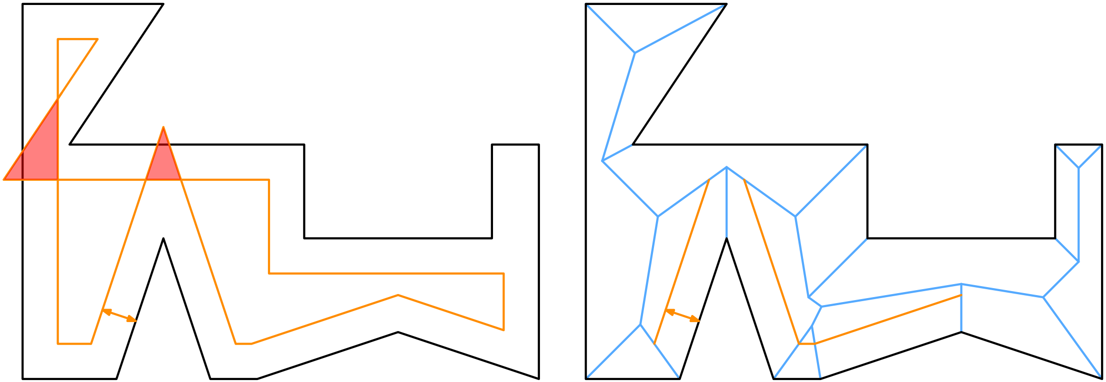

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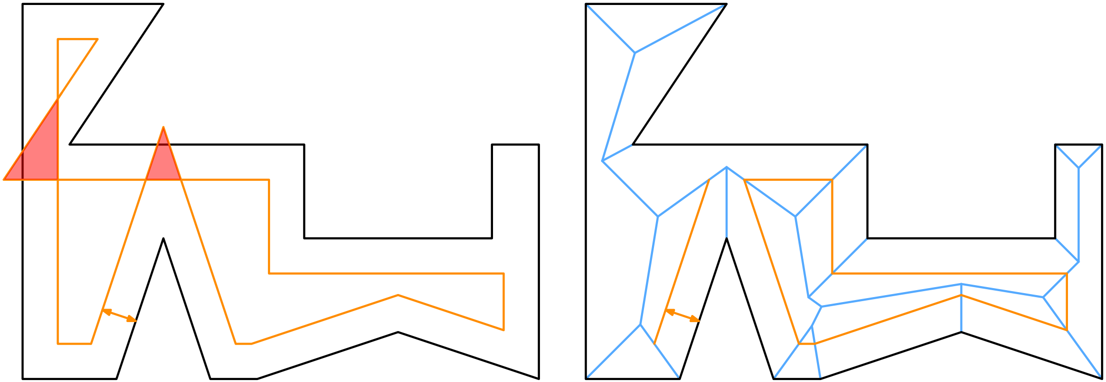

Straight Skeleton – Application: Polygon Offsetting

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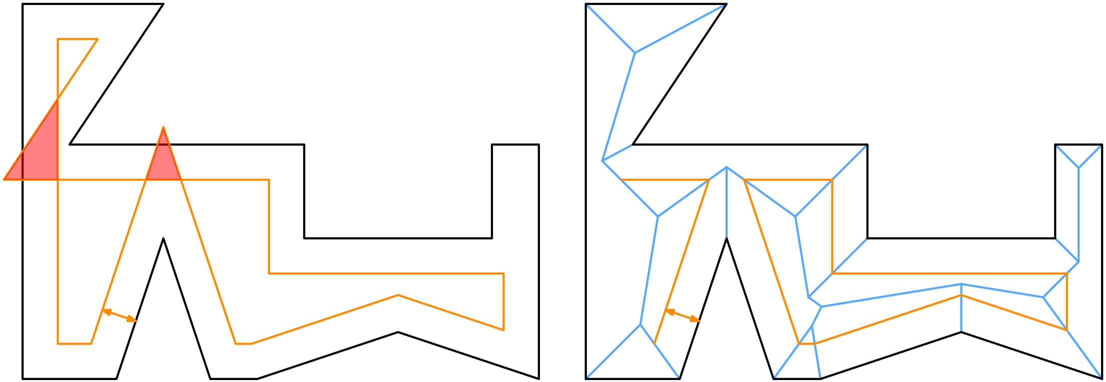

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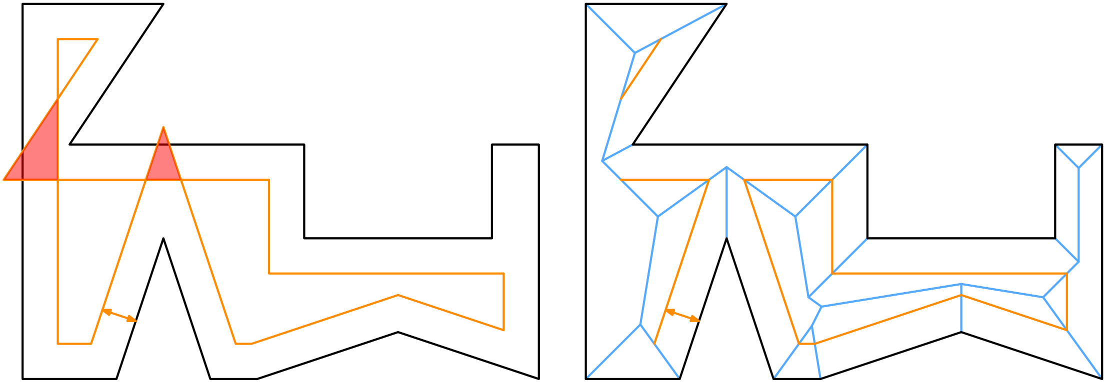

Straight Skeleton – Application: Polygon Offsetting

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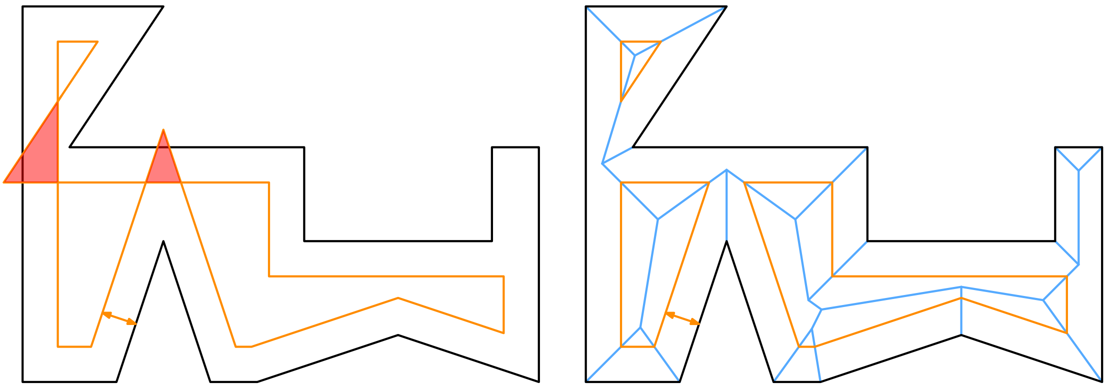

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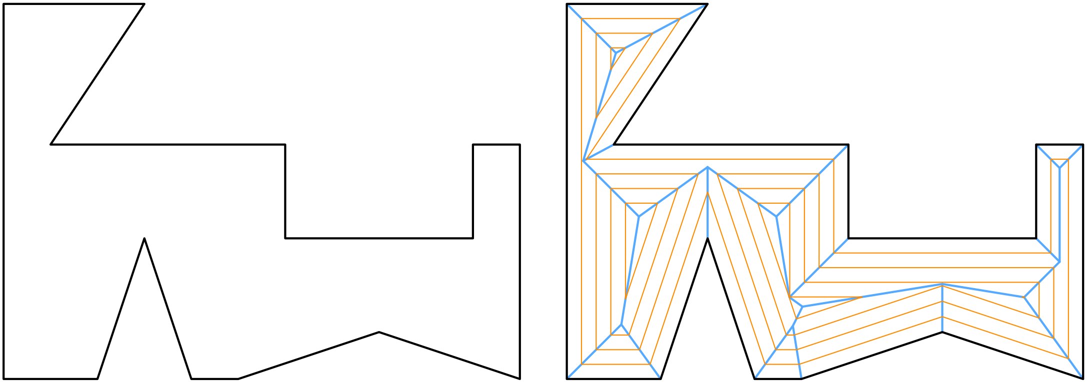

Straight Skeleton – Application: Automated Roof Construction

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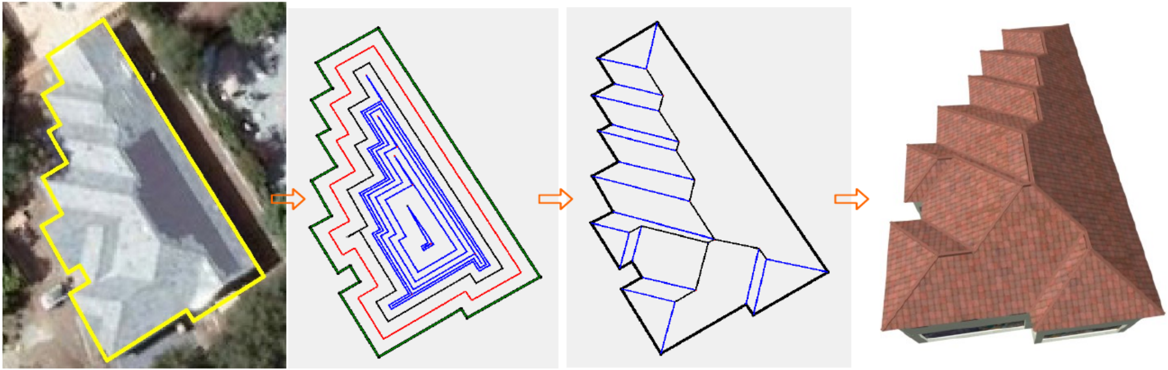
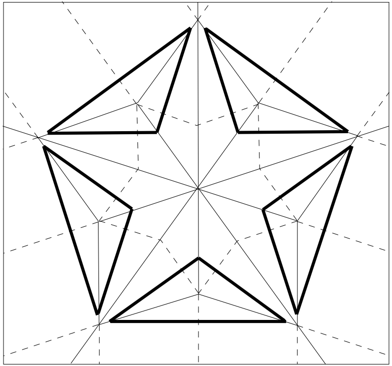
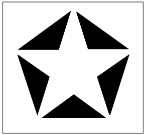
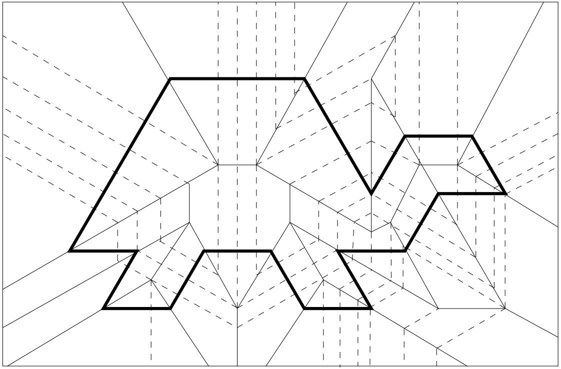


[5] Sugihara and Khmelevsky - Roof report from automatically generated 3D building models by straight skeleton computation

Straight Skeleton – Application: Mathematical Origami



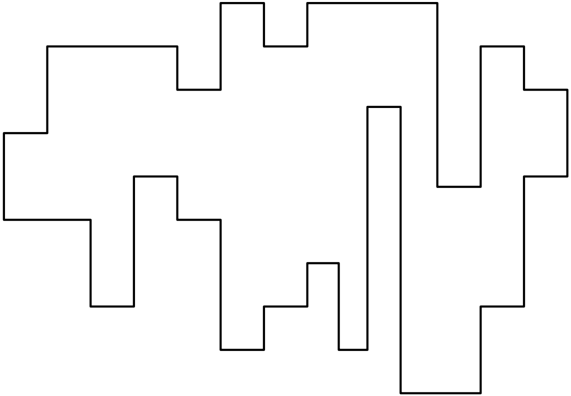




[2] Demaine et al. - Folding and One Straight Cut Suffice

Straight Skeleton – Our Result

- Straight skeleton of an orthogonal monotone polygon.
- Linear time algorithm.
- Best known approaches:
  - Straight skeleton – $\mathcal{O}(n^{17/11+\epsilon})$ [3]
  - Voronoi diagram L_∞ – $\mathcal{O}(n \log n)$ [4]



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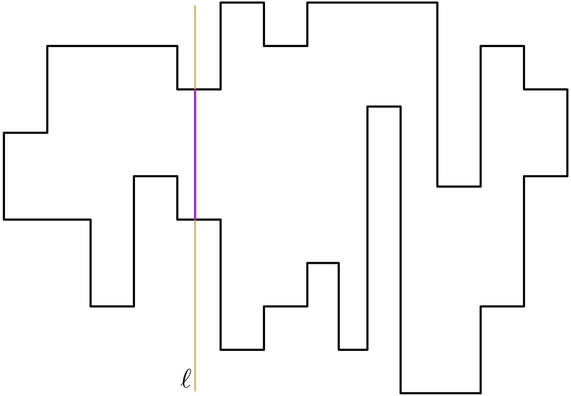

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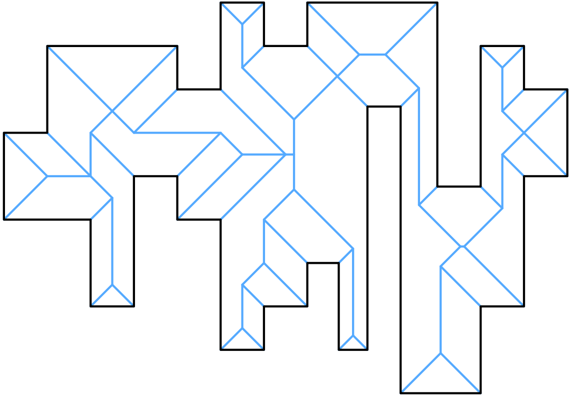

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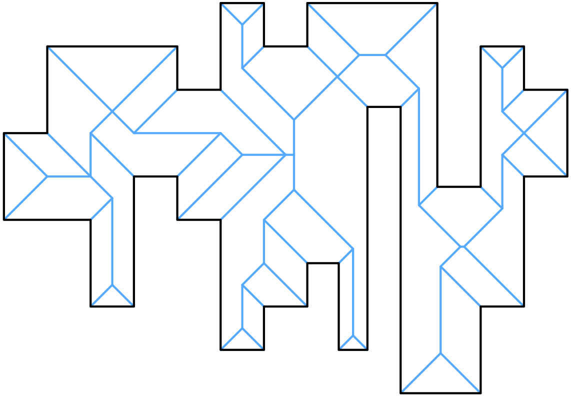

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UNIVERSITY OF SALZBURG
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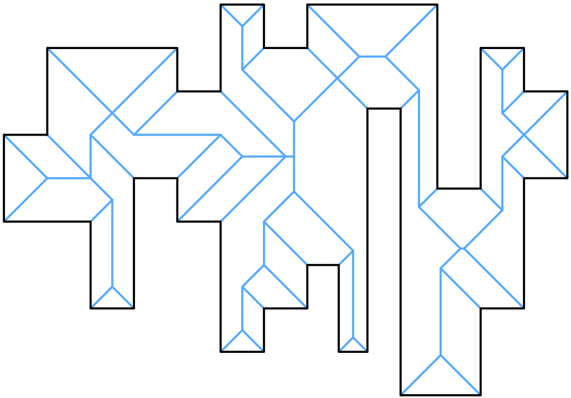

[3] Eppstein and Erickson - Raising Roofs, Crashing Cycles, and Playing Pool

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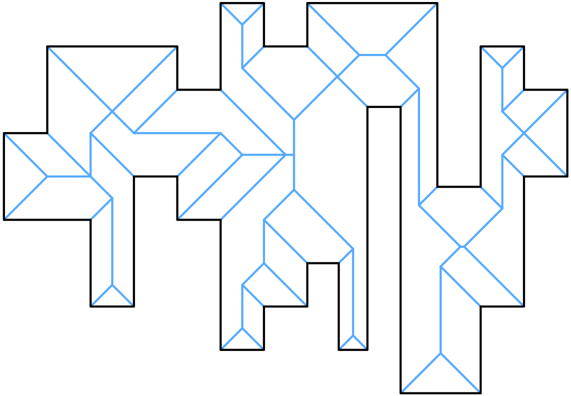
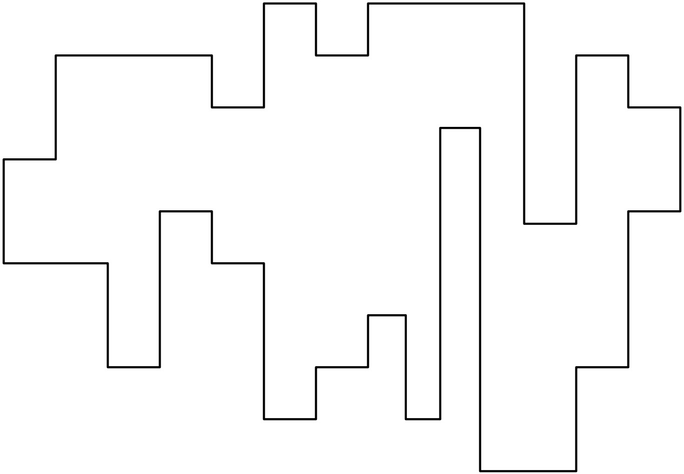


[3] Eppstein and Erickson - Raising Roofs, Crashing Cycles, and Playing Pool – [4] Papadopoulou et al. - The L_∞ Voronoi Diagram of Segments

Straight Skeleton – Algorithm



Straight Skeleton – Algorithm

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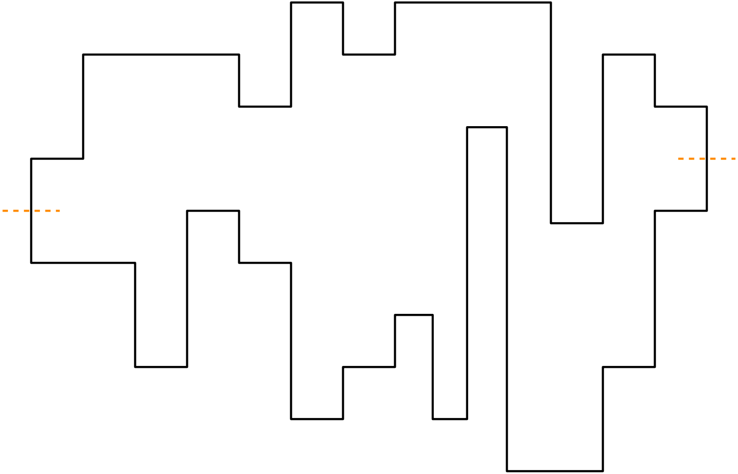

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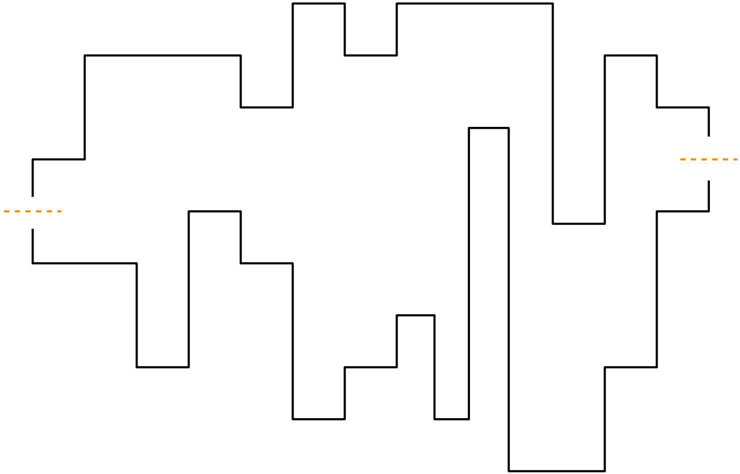

Straight Skeleton – Algorithm

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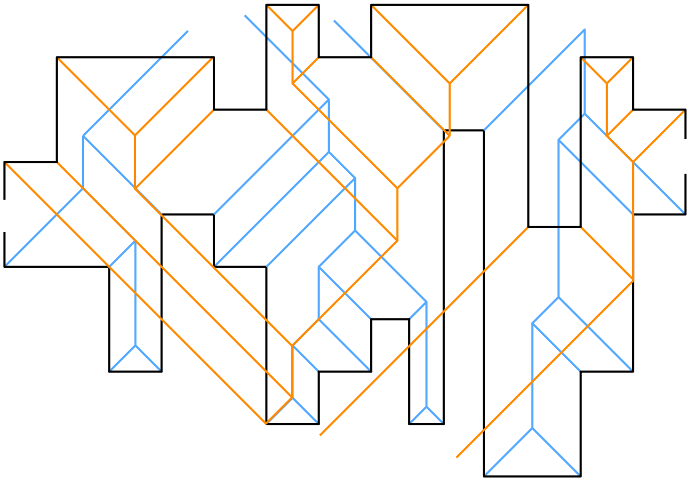

Straight Skeleton – Algorithm

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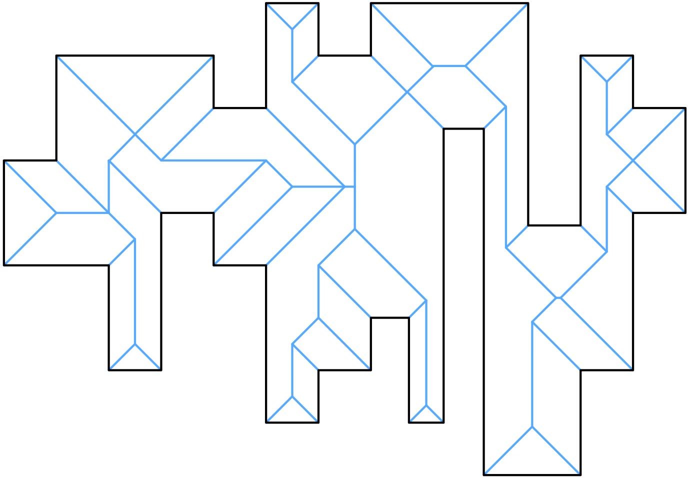

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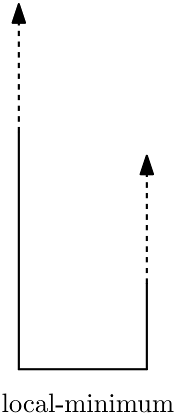
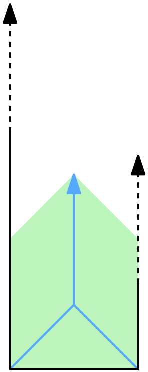


Straight Skeleton – Algorithm



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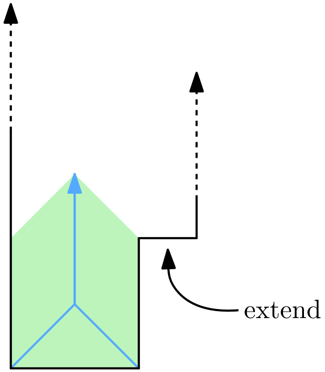

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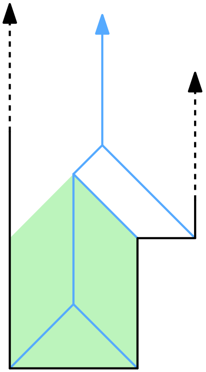

Straight Skeleton – Algorithm

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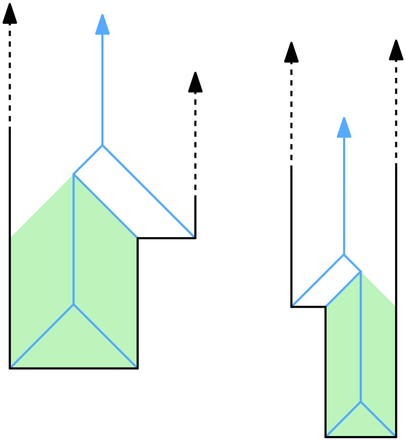

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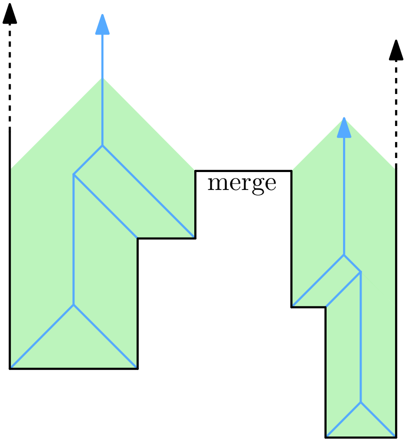

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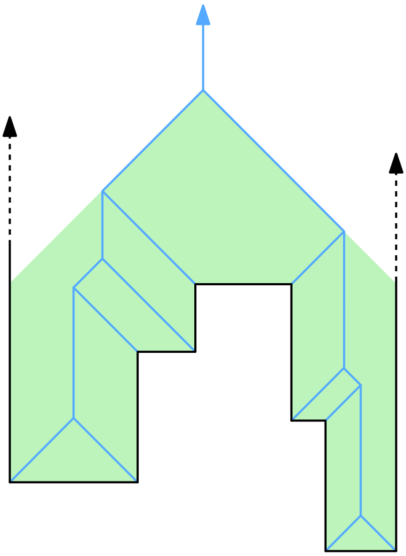

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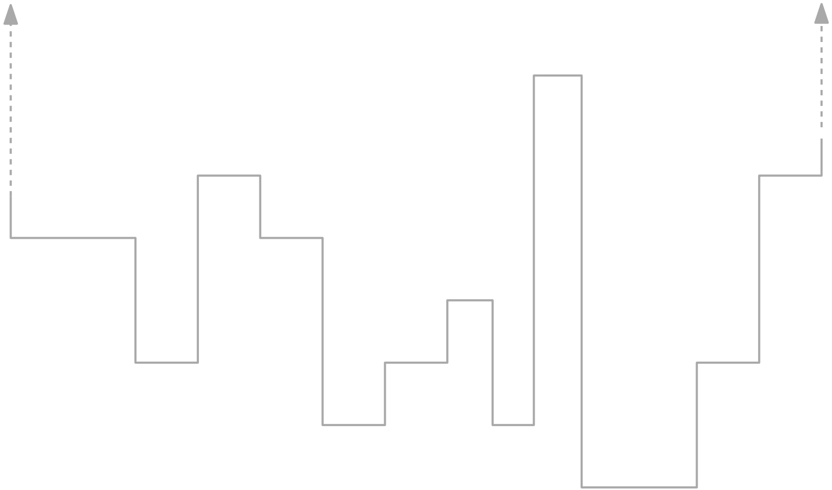

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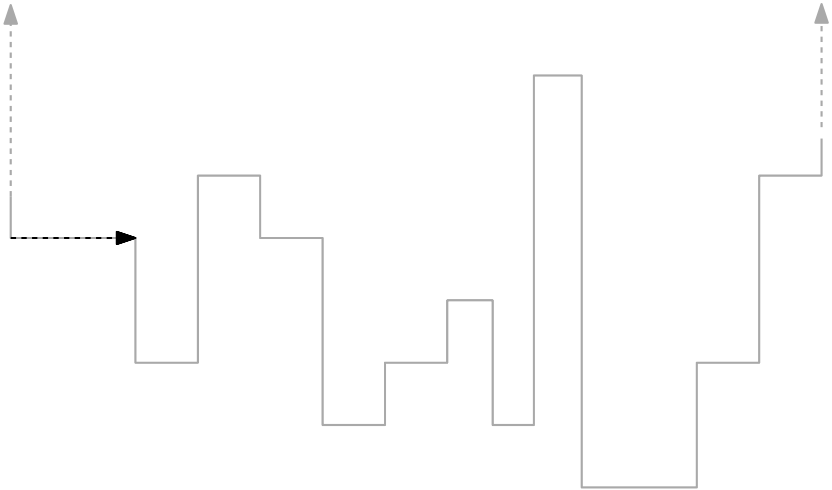

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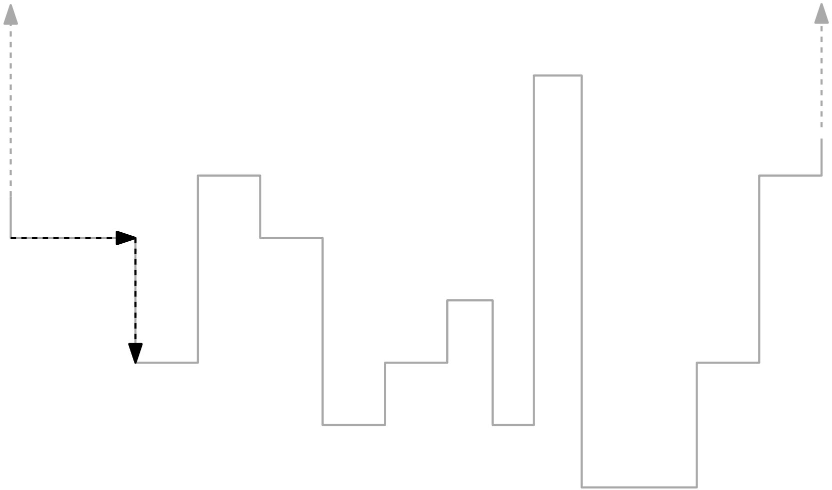

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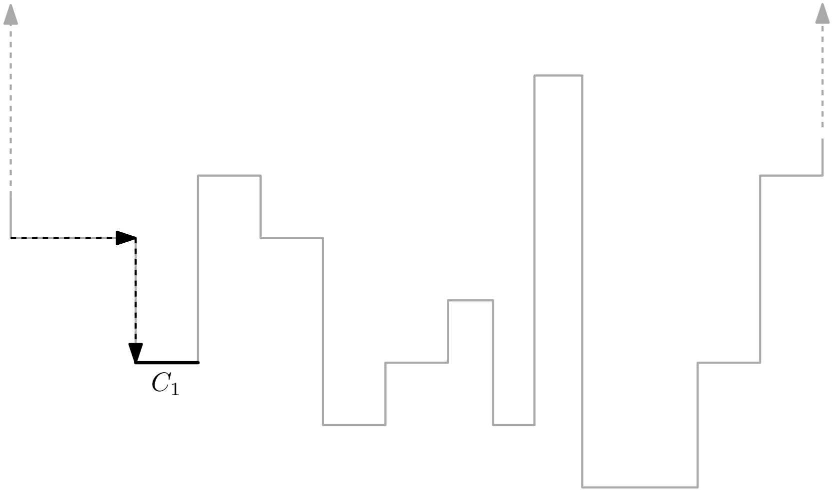

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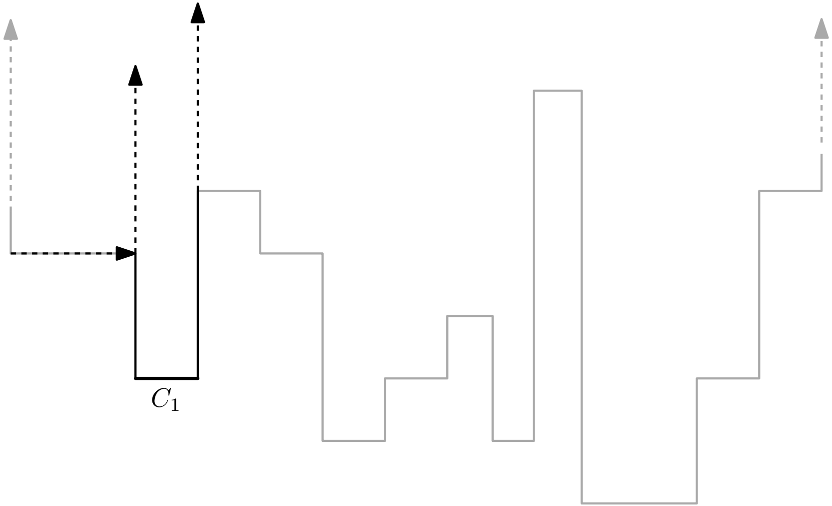

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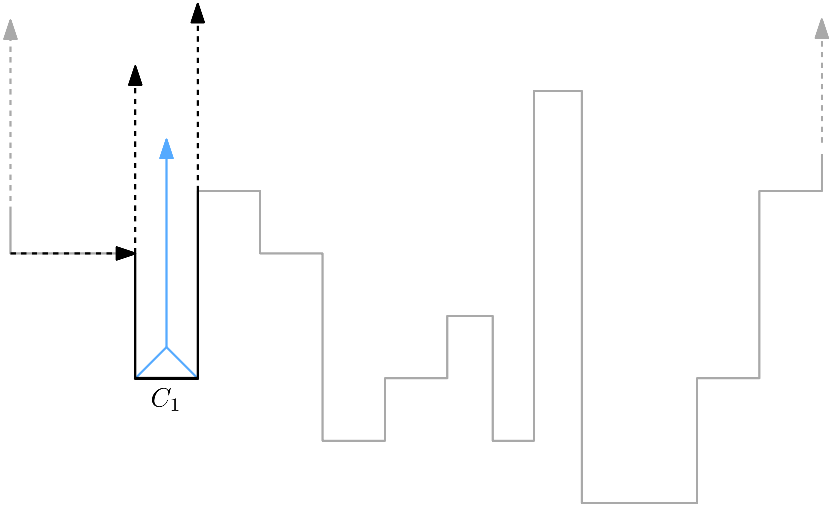

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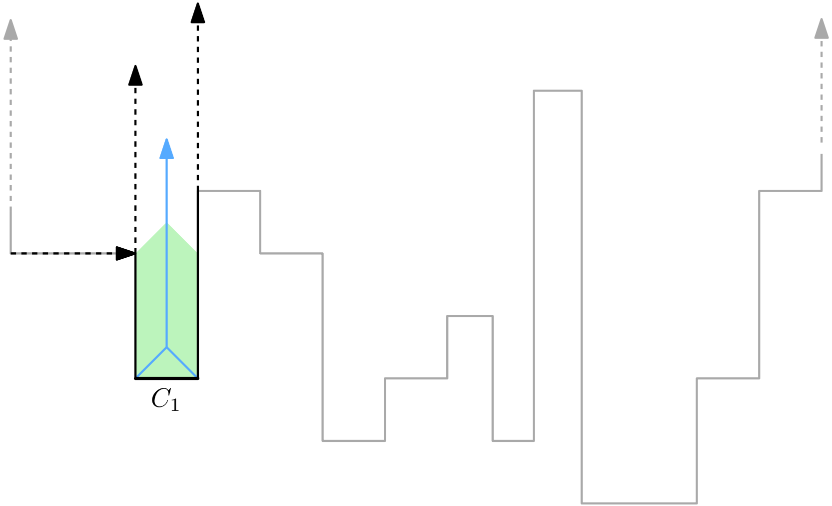

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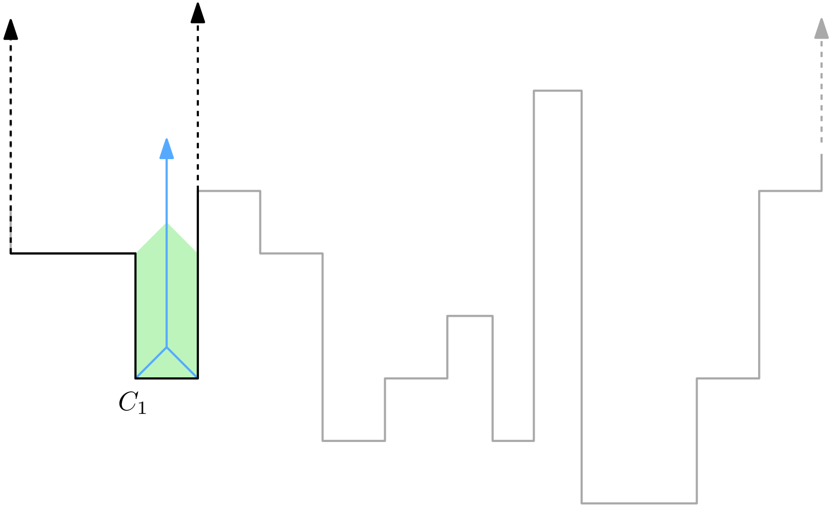

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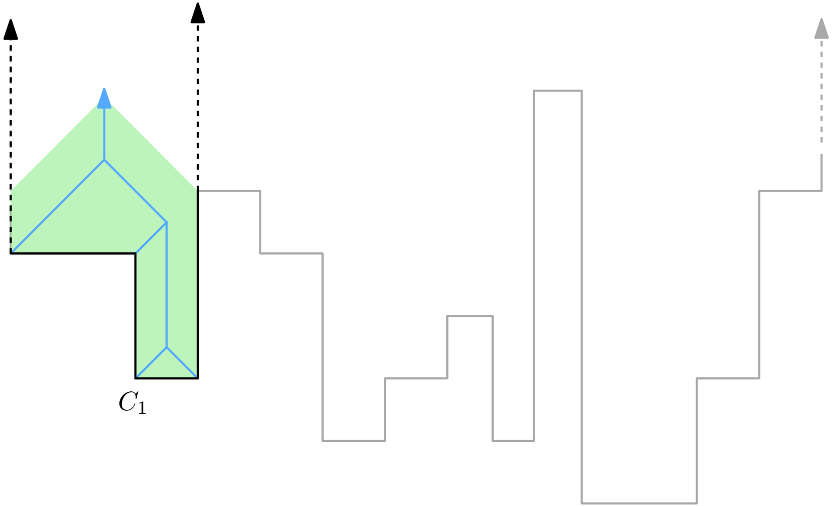

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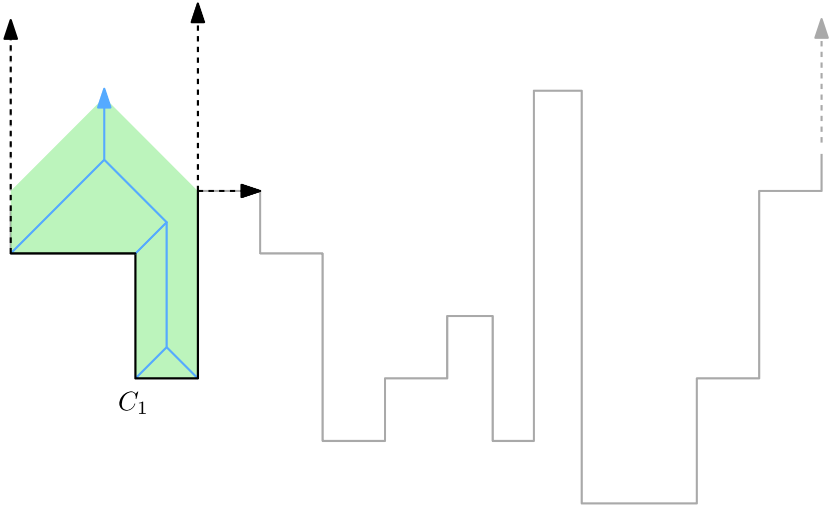

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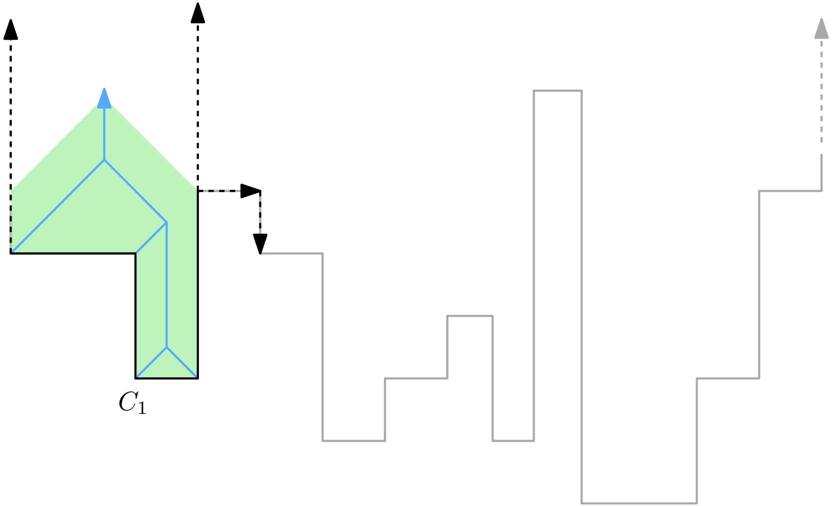

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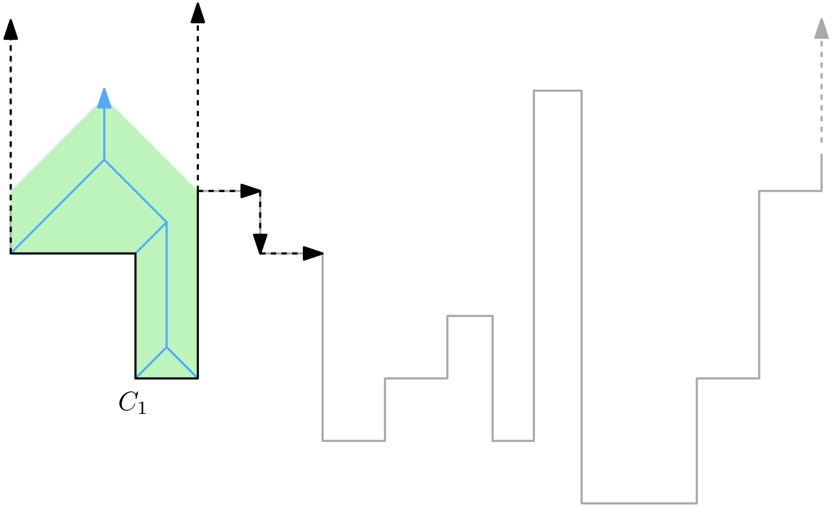

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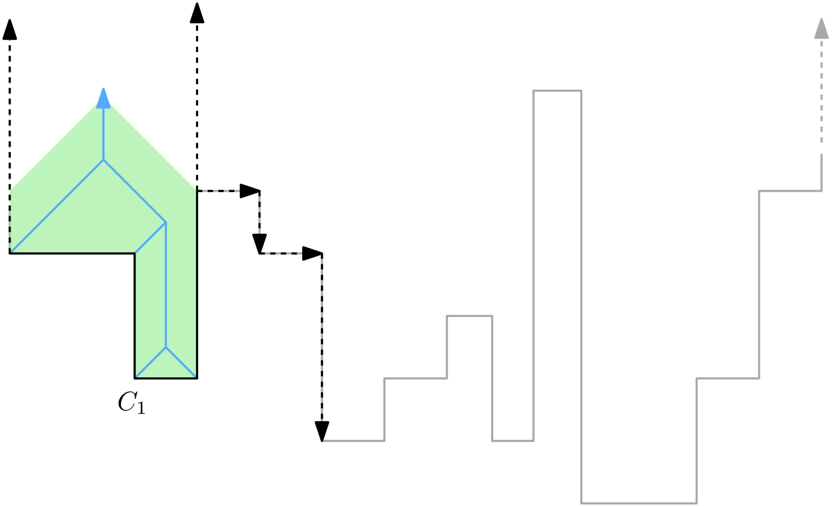

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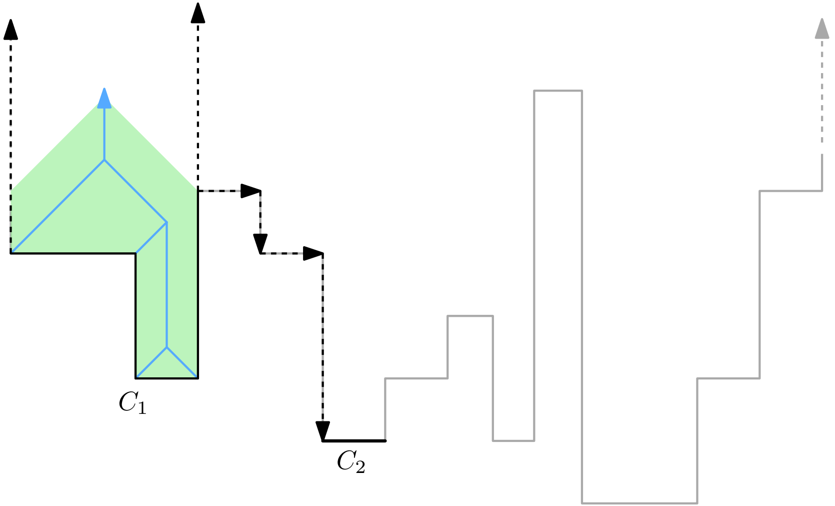

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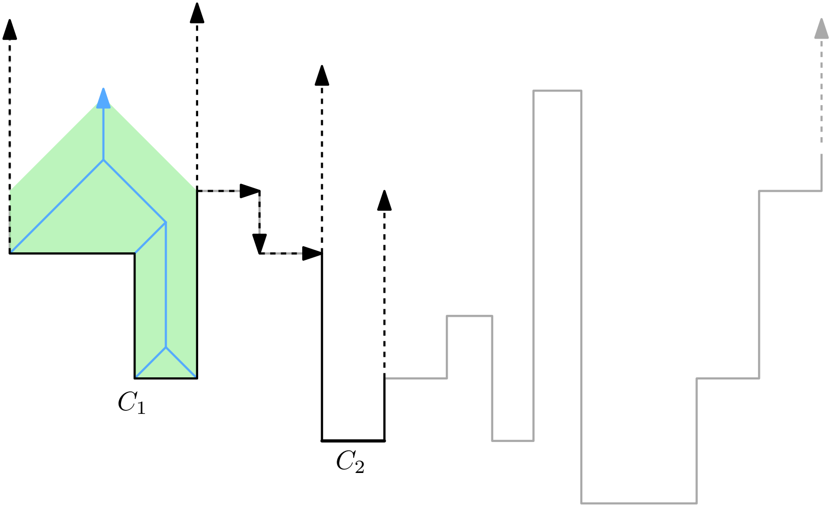

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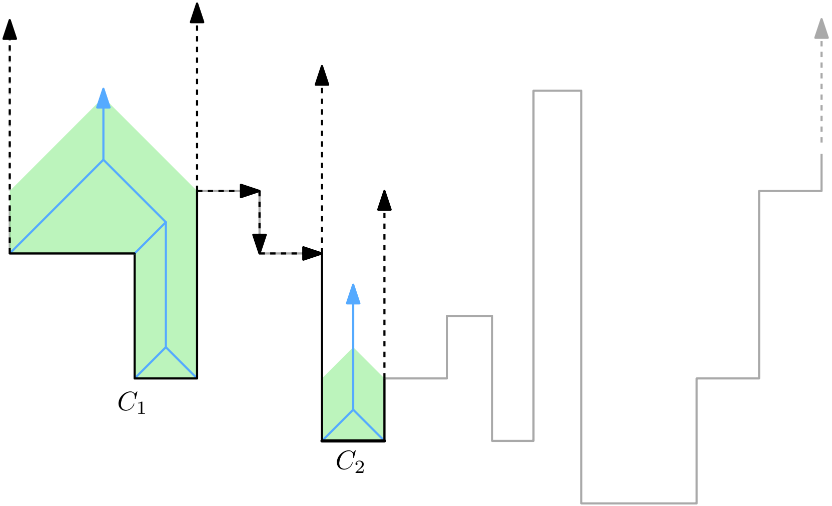

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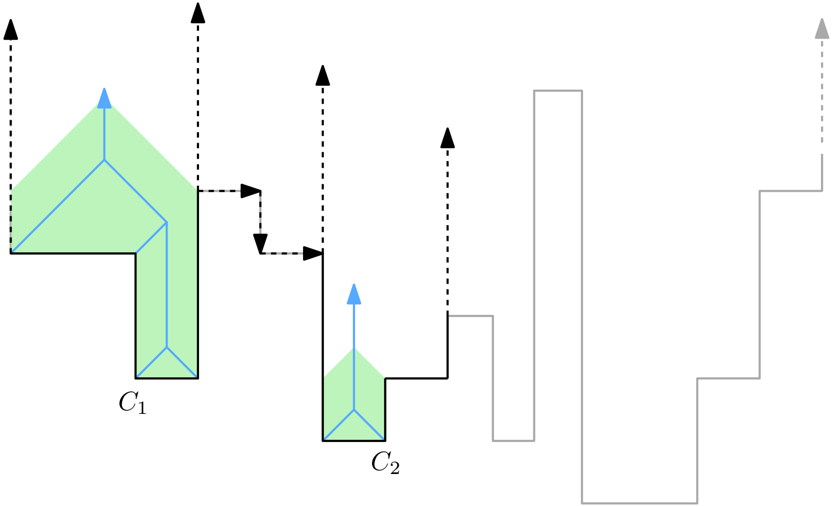

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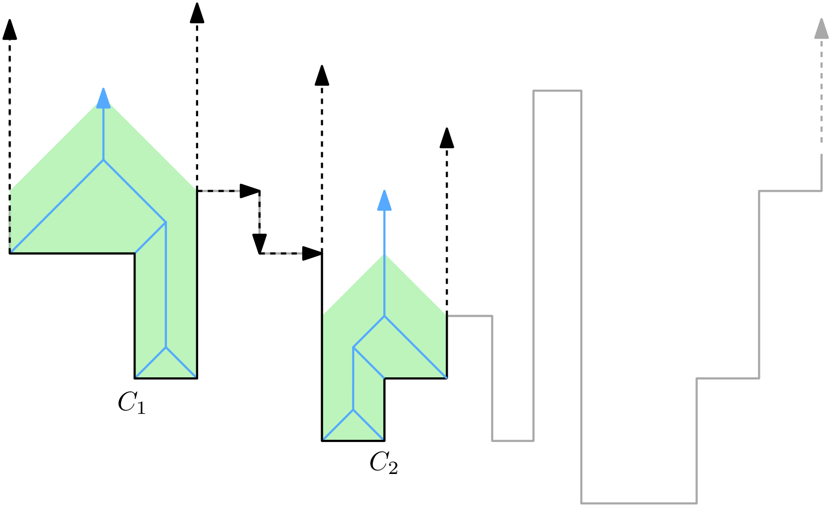

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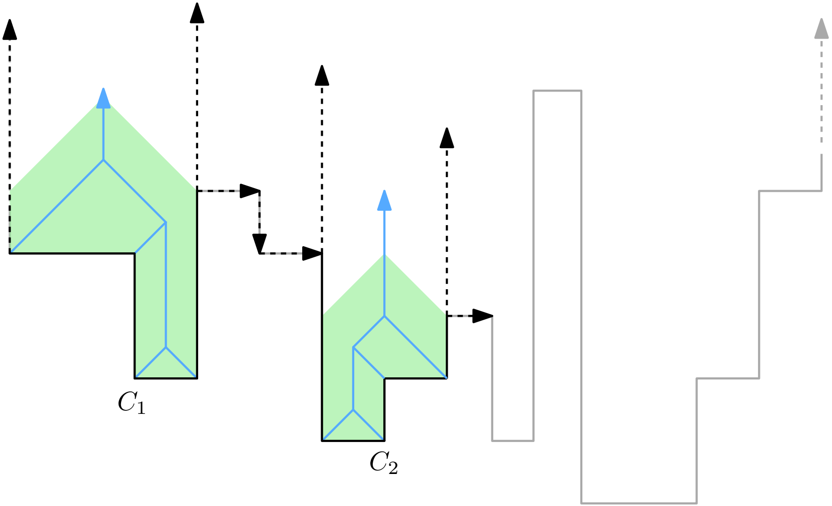

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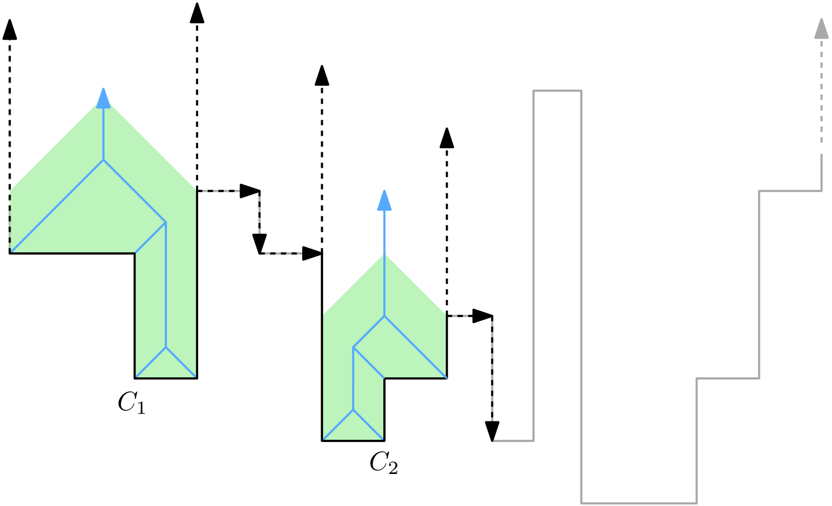

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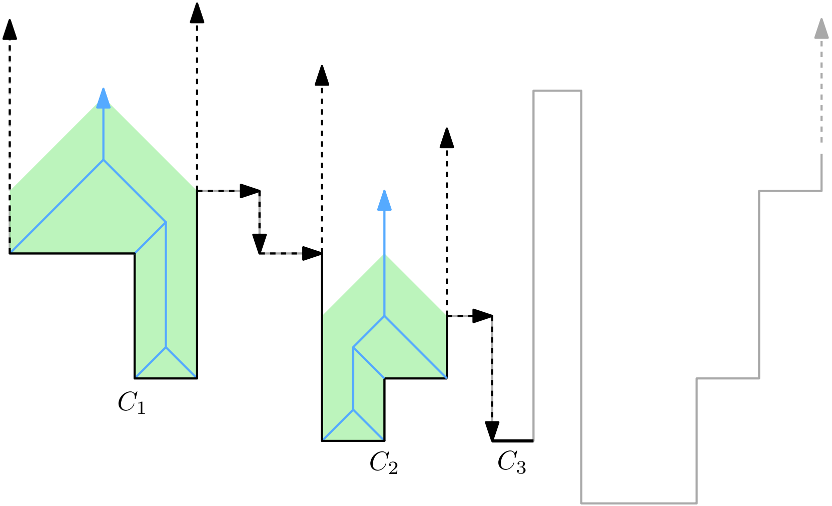

Straight Skeleton – Algorithm

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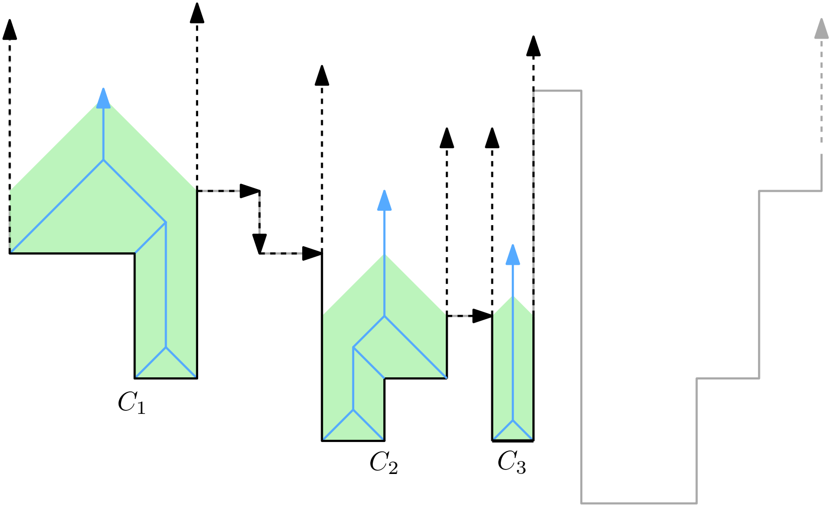

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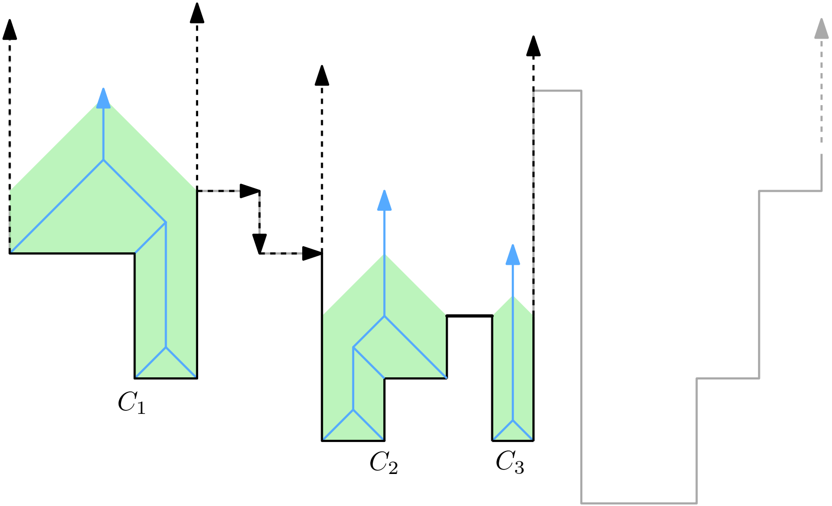

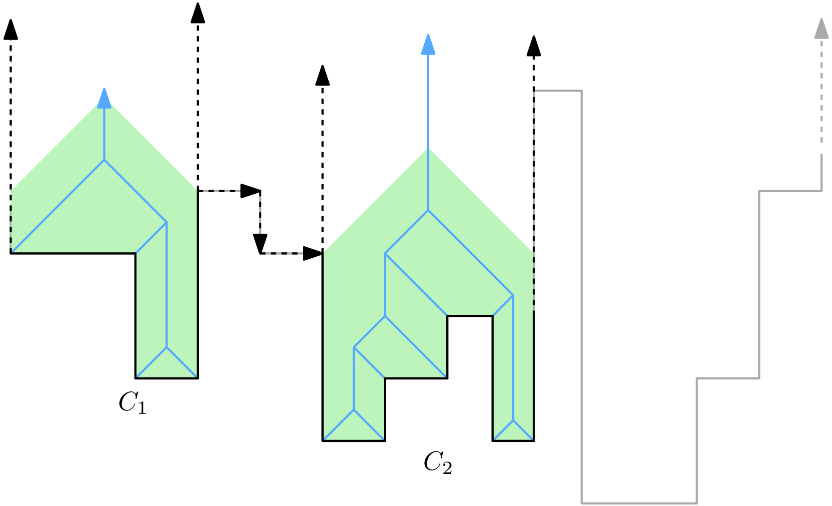
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C_2

Straight Skeleton – Algorithm

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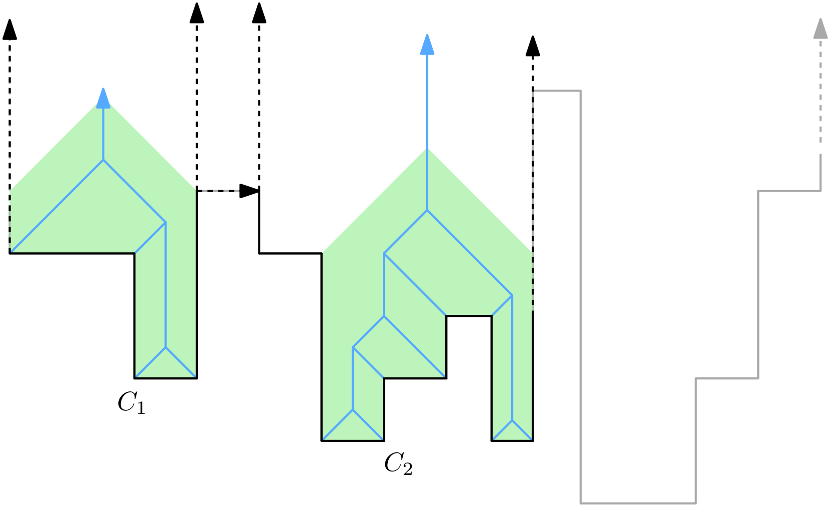

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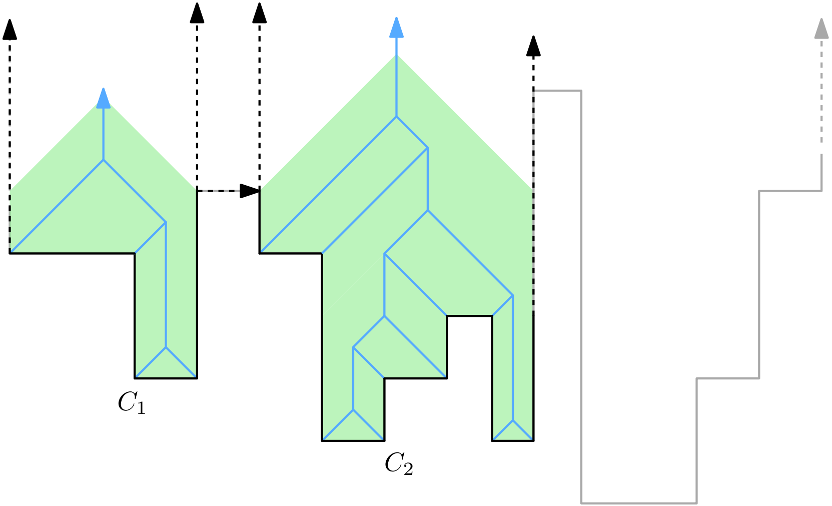

Straight Skeleton – Algorithm

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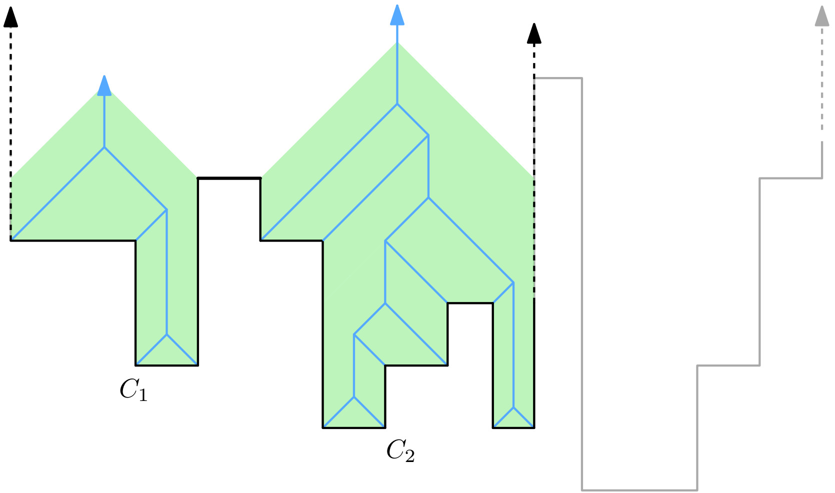

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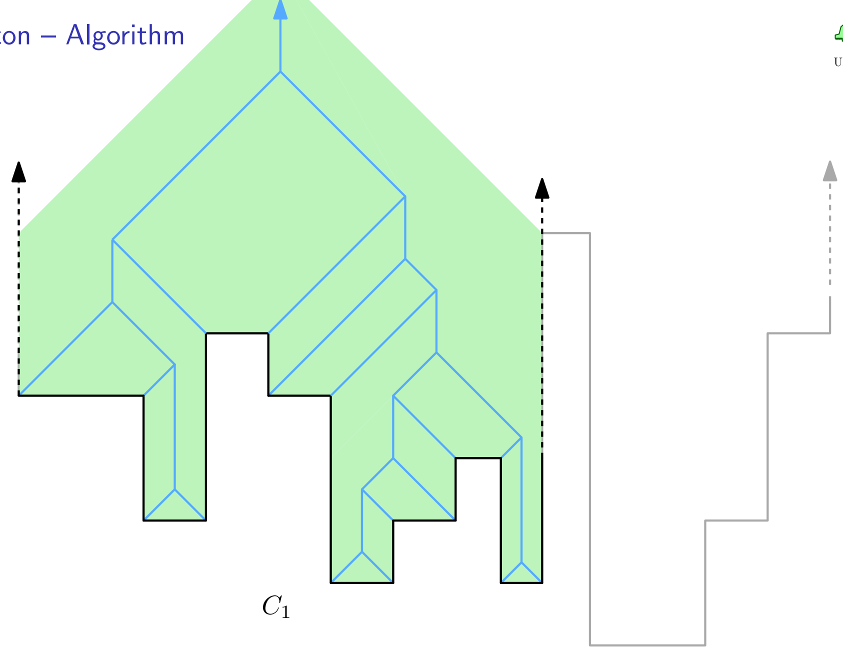

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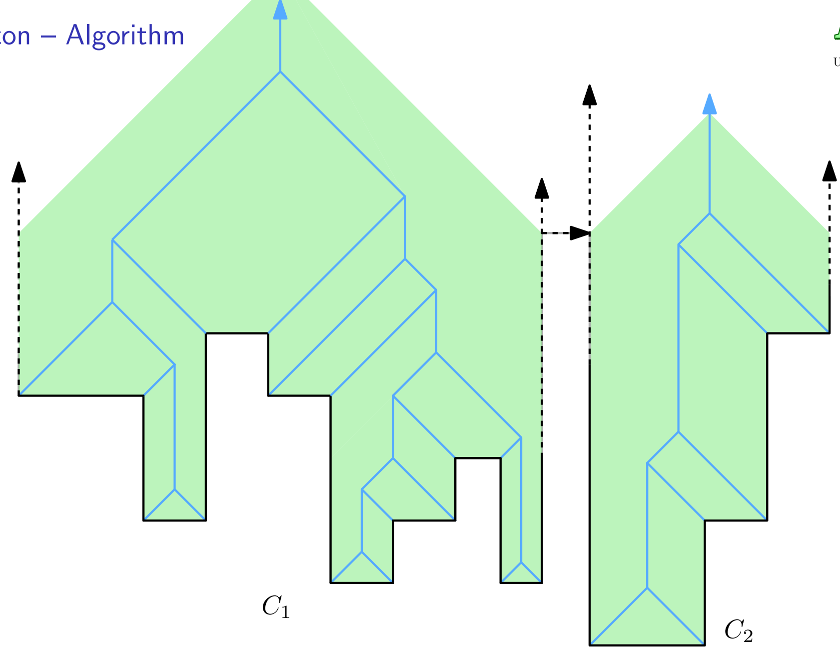

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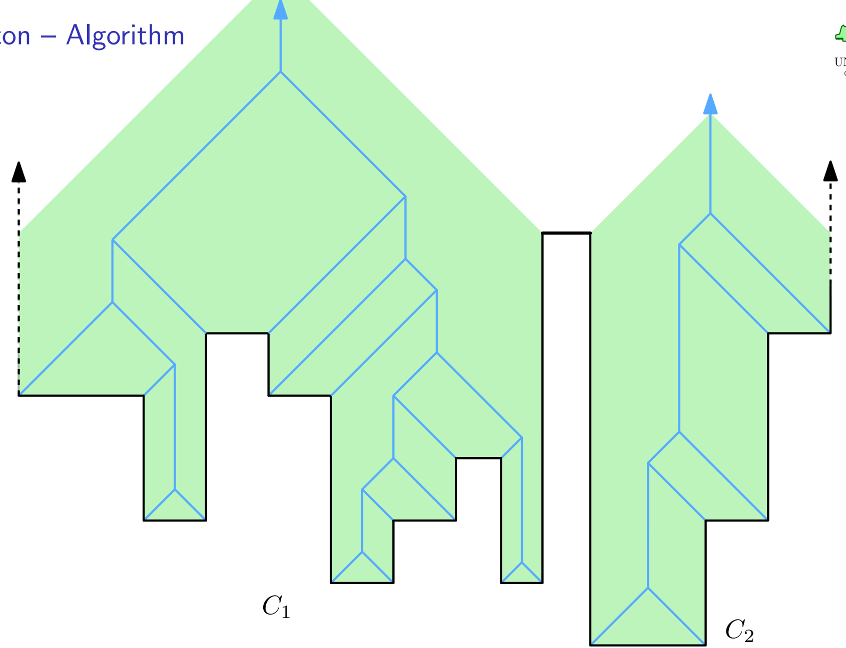

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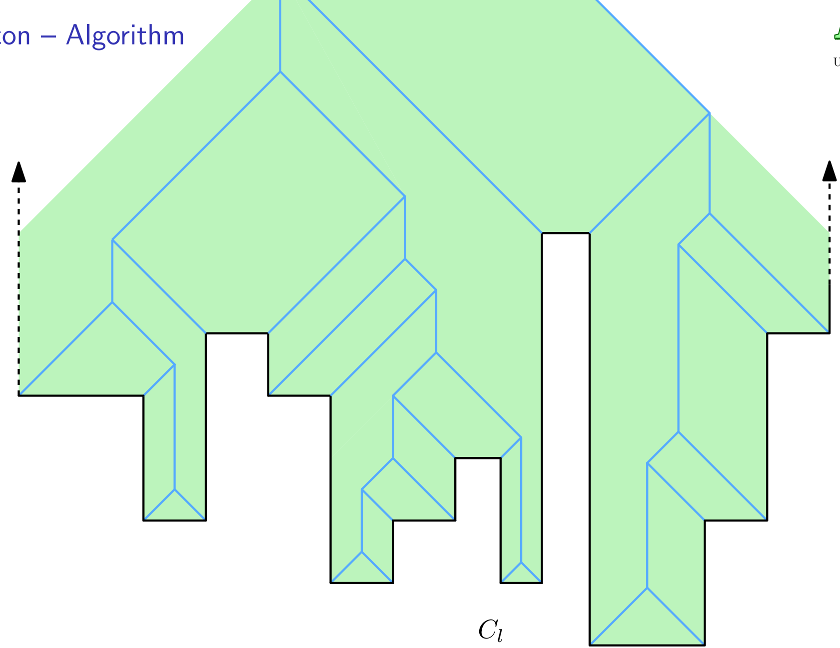

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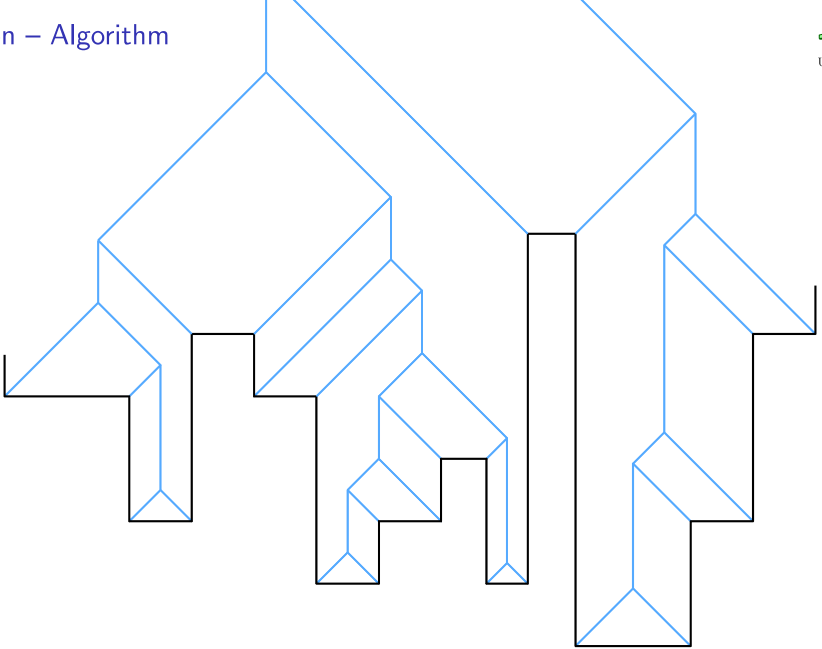

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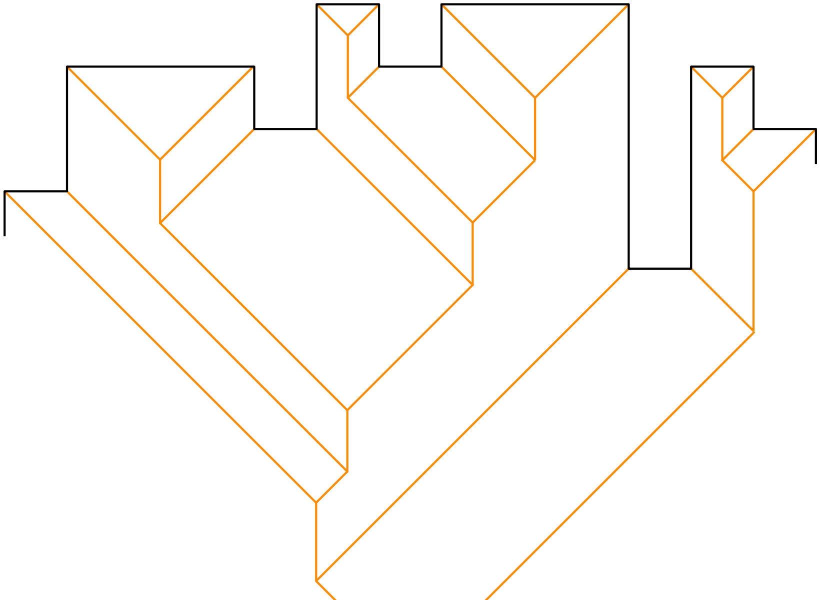

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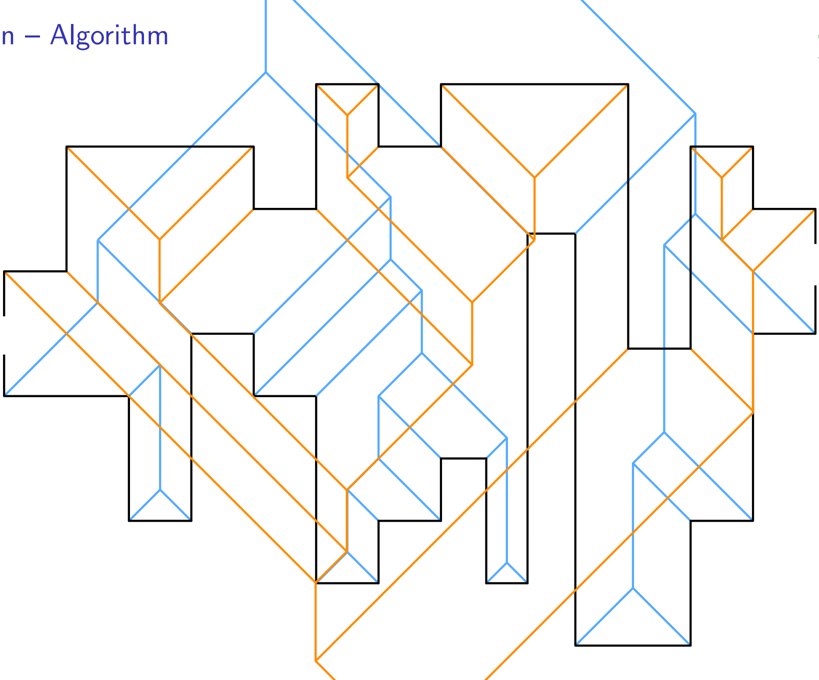

Straight Skeleton – Algorithm

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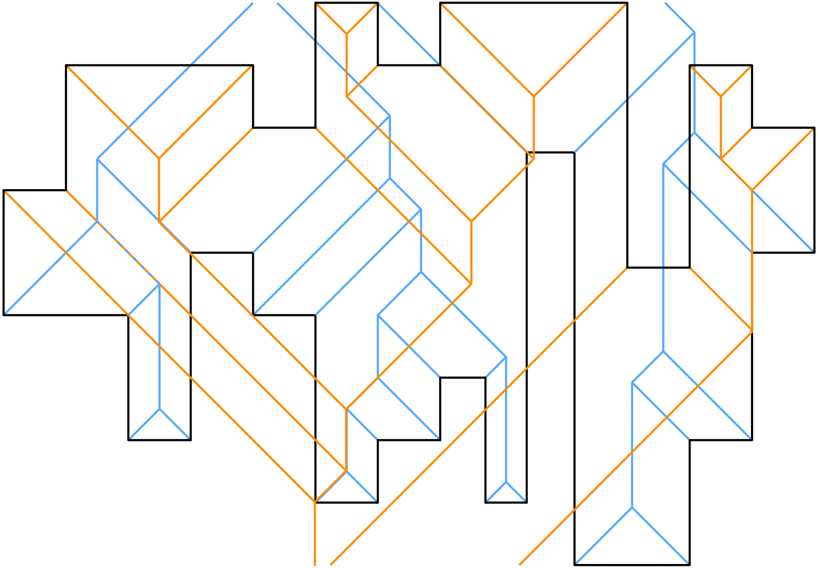

Straight Skeleton – Algorithm

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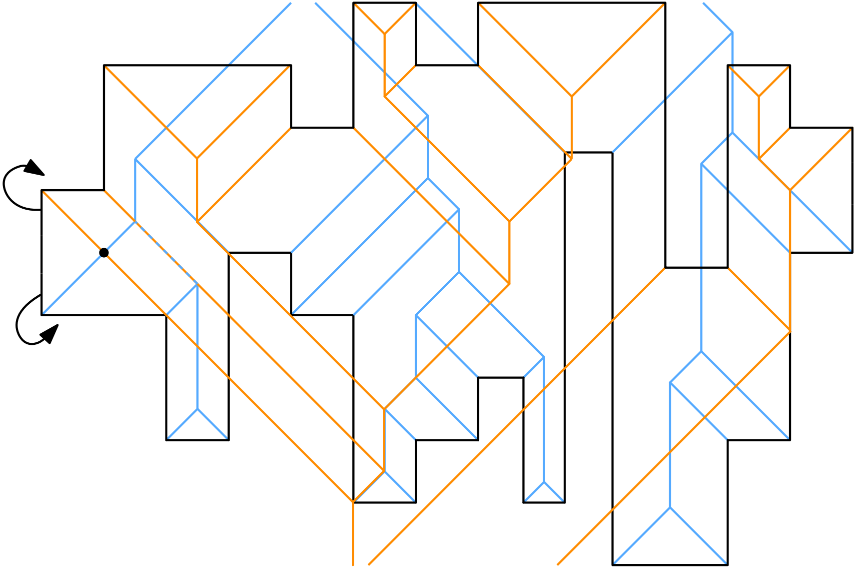

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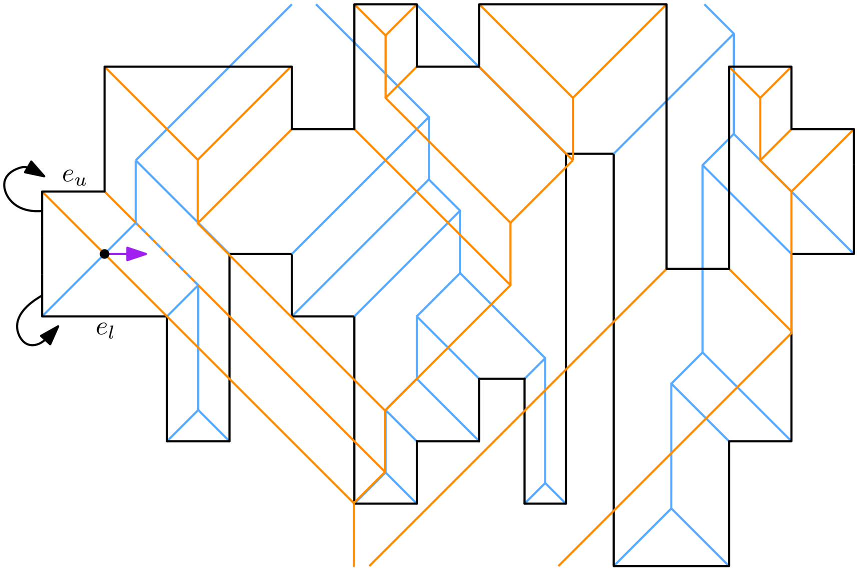

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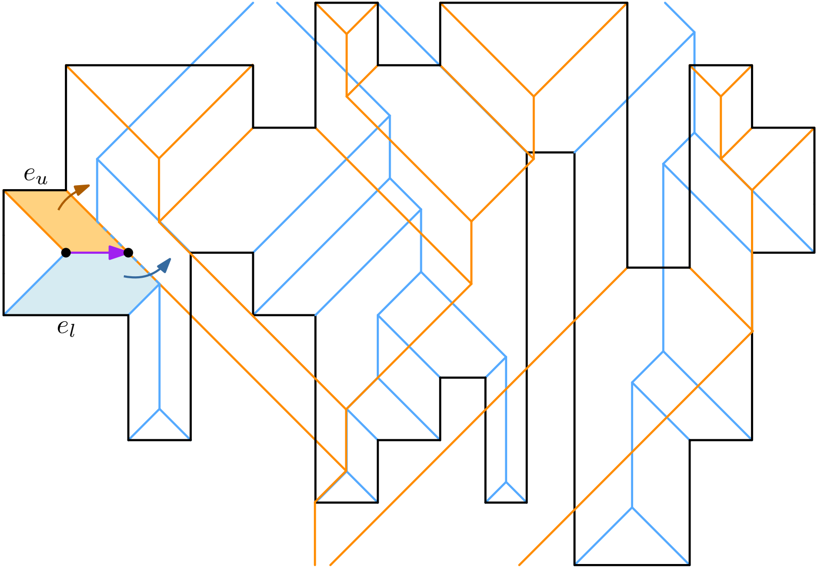

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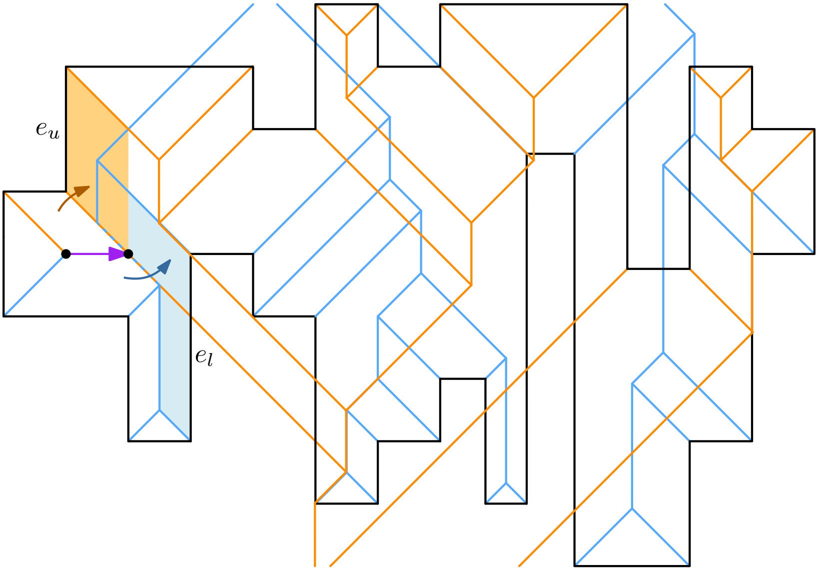

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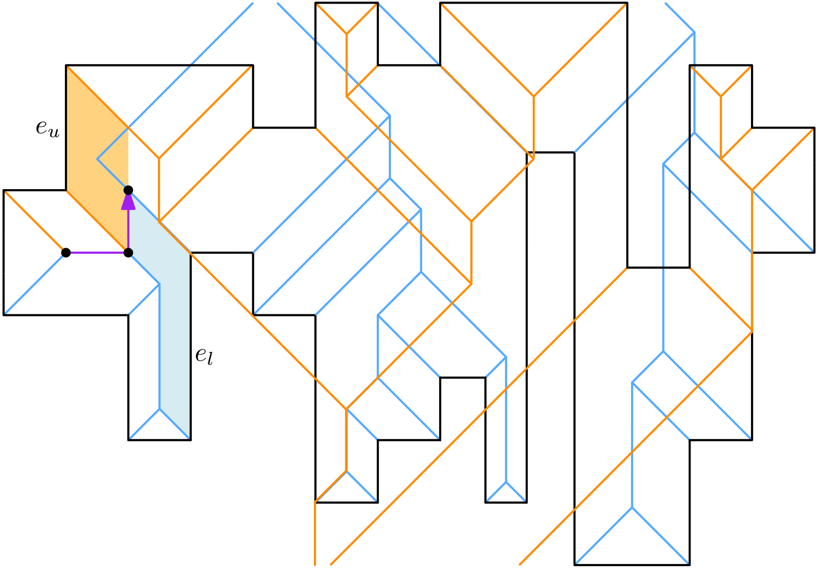

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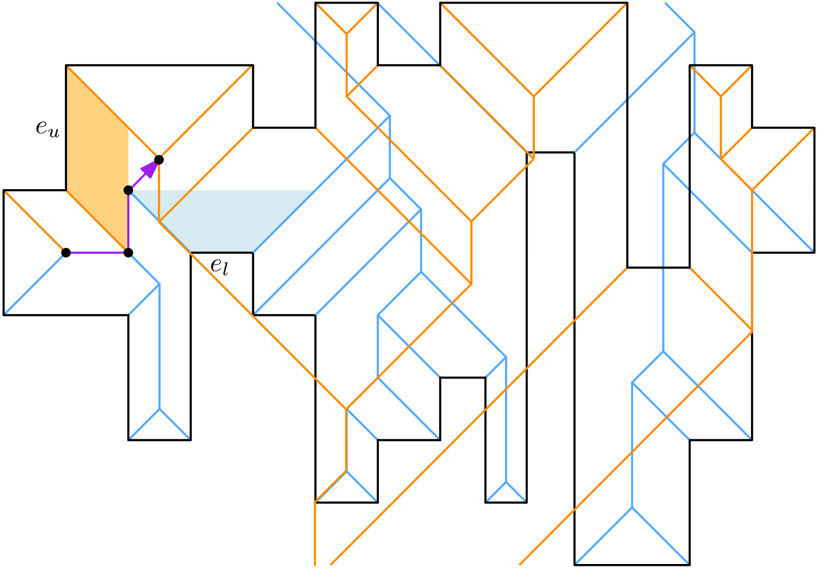

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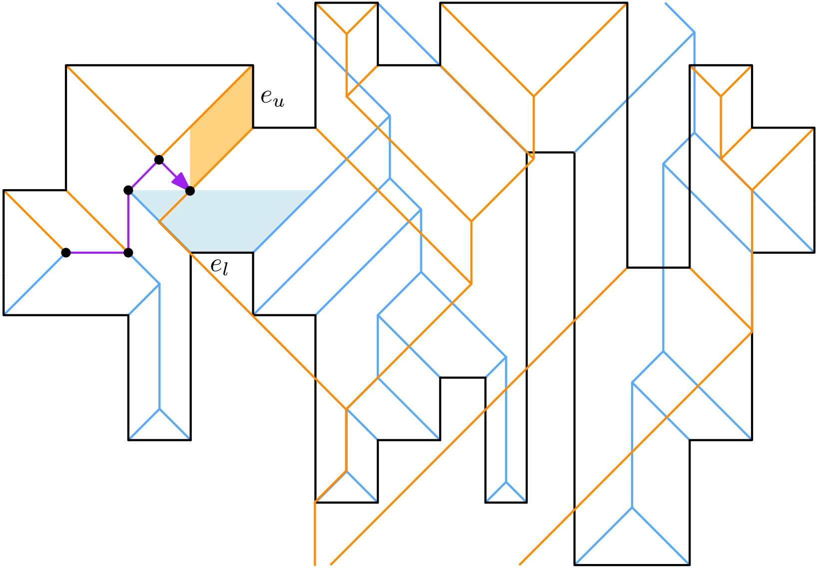

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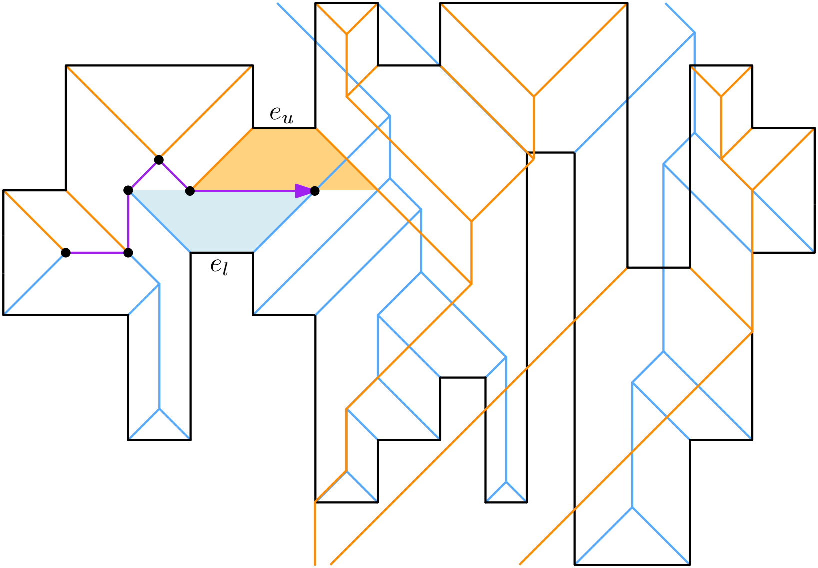

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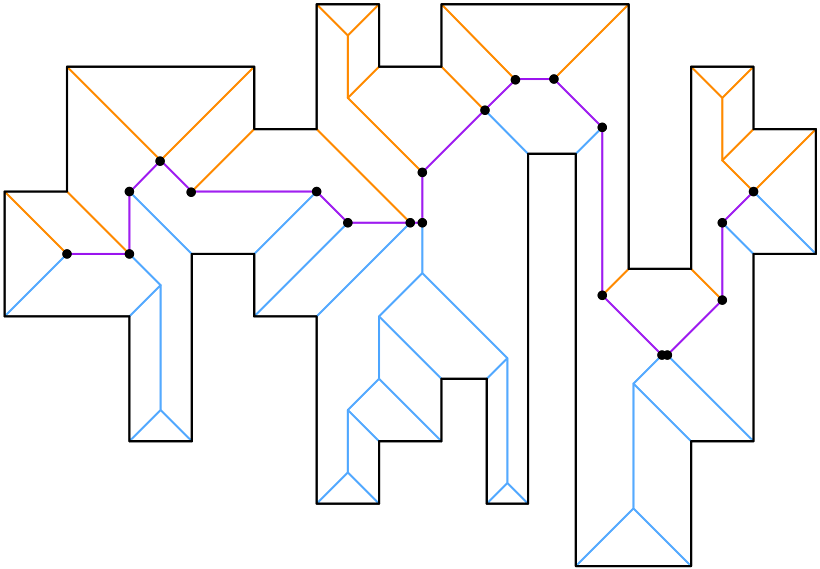

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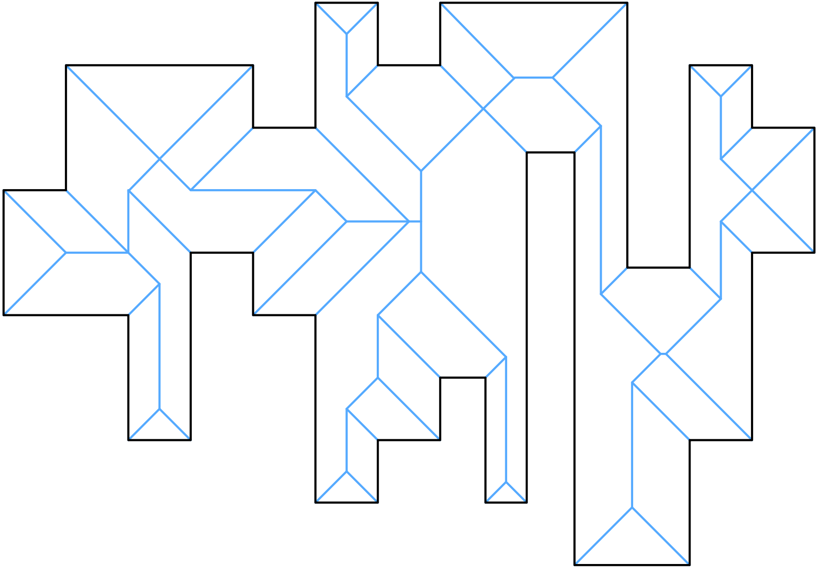

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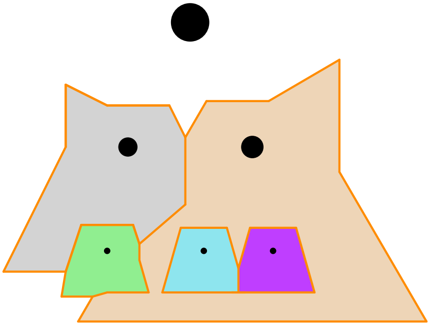
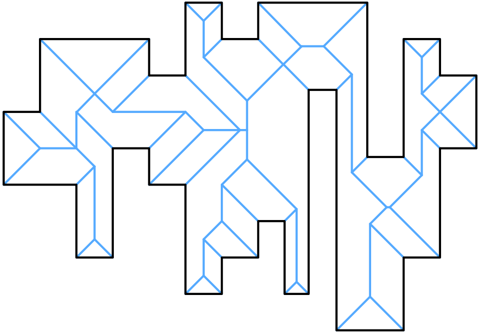


Weighted Voronoi Diagram L_∞



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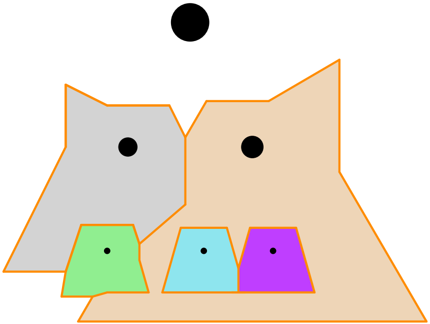

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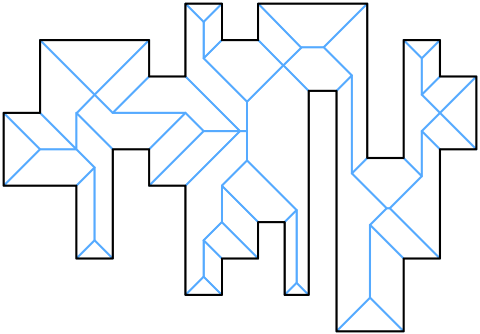

Straight Skeleton

Questions?

References I

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[2] E. D. Demaine, M. L. Demaine, and A. Lubiw. Folding and One Straight Cut Suffice. In *Proceedings of the 10th Symposium on Discrete Algorithms (SODA 1999)*, pages 891–892.

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[4] E. Papadopoulou and D. Lee. The L_∞ Voronoi Diagram of Segments and VLSI Applications. *International Journal of Computational Geometry*, 11(05):503–528, 2001.

[5] K. Sugihara and Y. Khmelevsky. Roof report from automatically generated 3d building models by straight skeleton computation. In *2018 Annual IEEE International Systems Conference (SysCon)*, pages 1–8, 2018.