

Continuously Generalizing Buildings to Built-up Areas by Aggregating and Growing

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zoom out



(Google Maps)

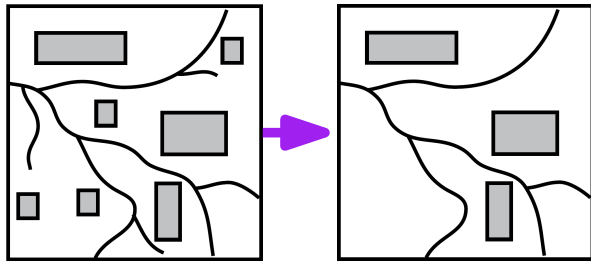
Map Generalization...

...is about **deriving** a **smaller-scale map** from an existing map.

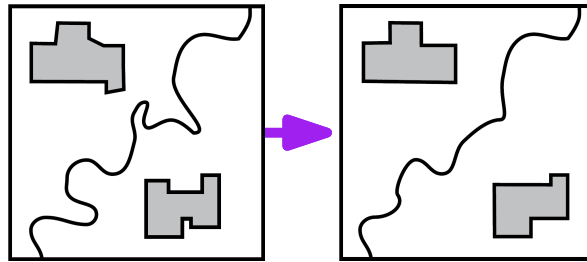
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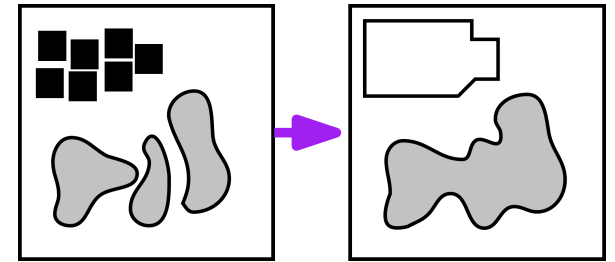
Typical **generalization operators** (ESRI 1996):



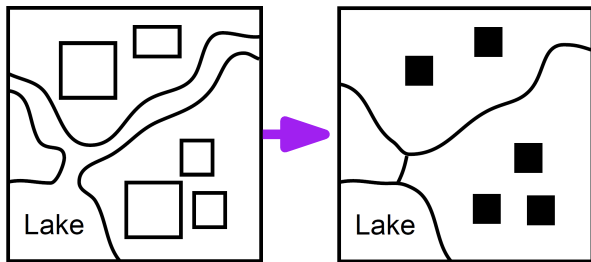
Elimination



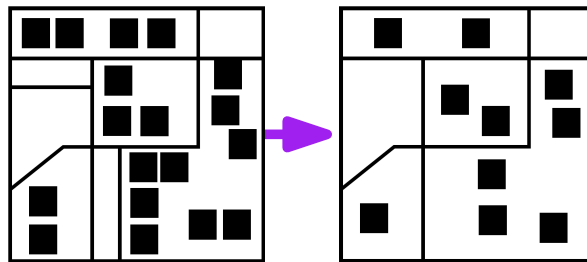
Simplification



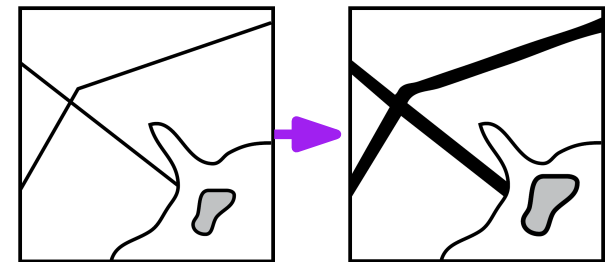
Aggregation



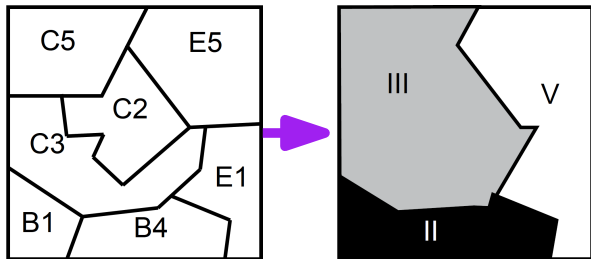
Collapse



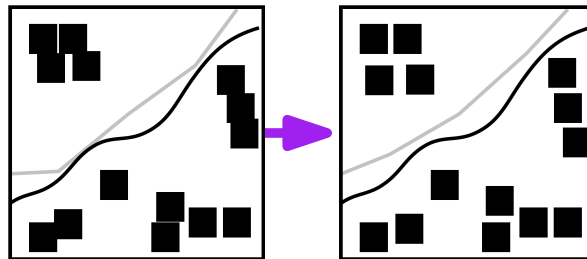
Typification



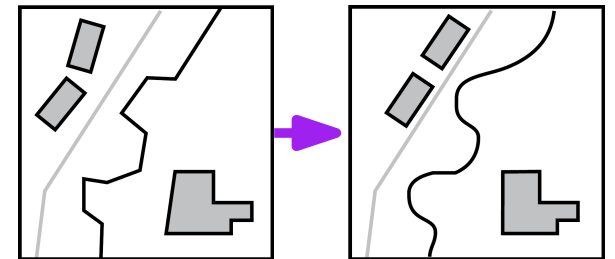
Exaggeration



Classifi. and symboli.



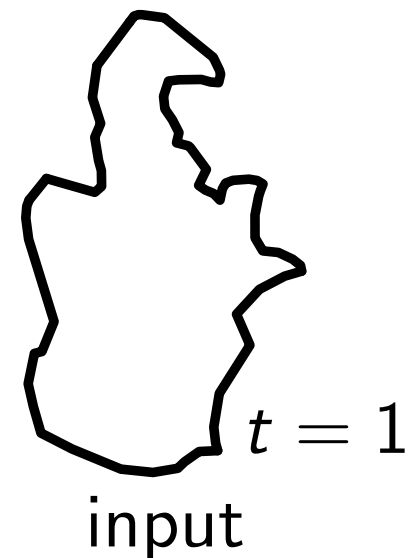
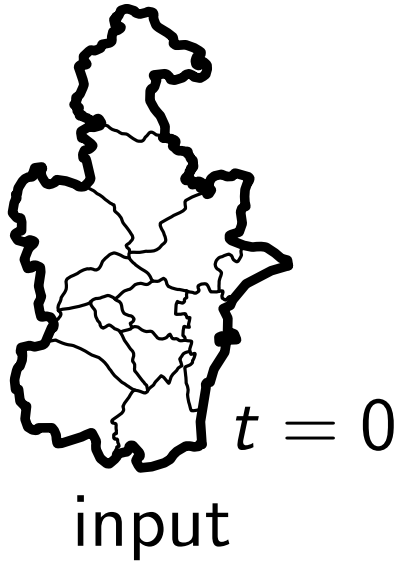
Displacement



Refinement

Continuous Map Generalization...

...is to derive a series of maps with **smooth changes**.

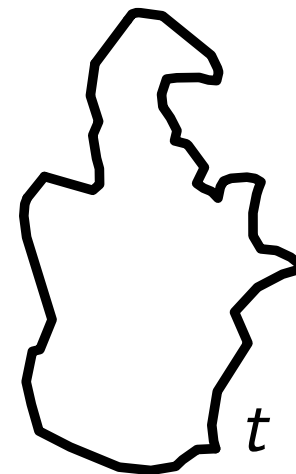
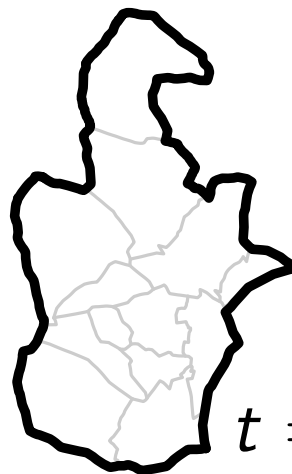
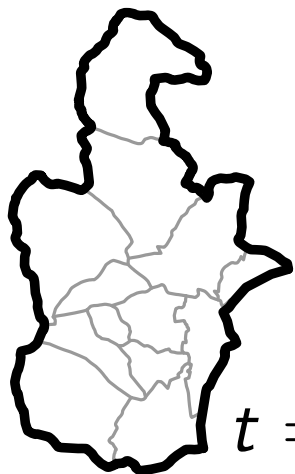


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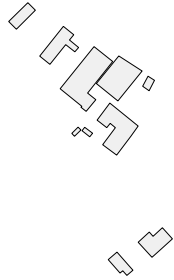
input



input

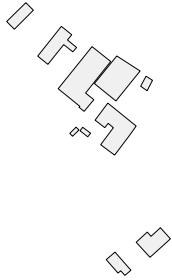
Research Problem

input

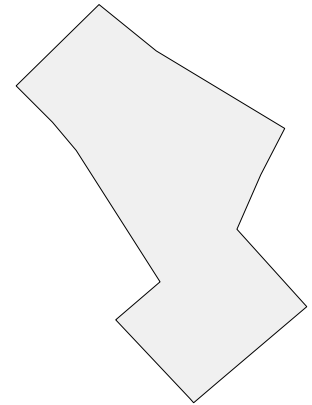


Research Problem

input

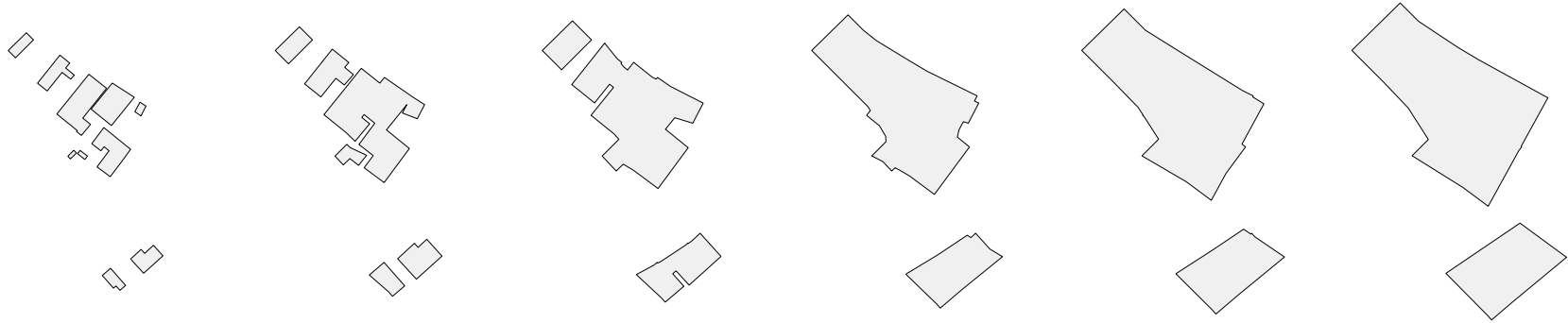


goal

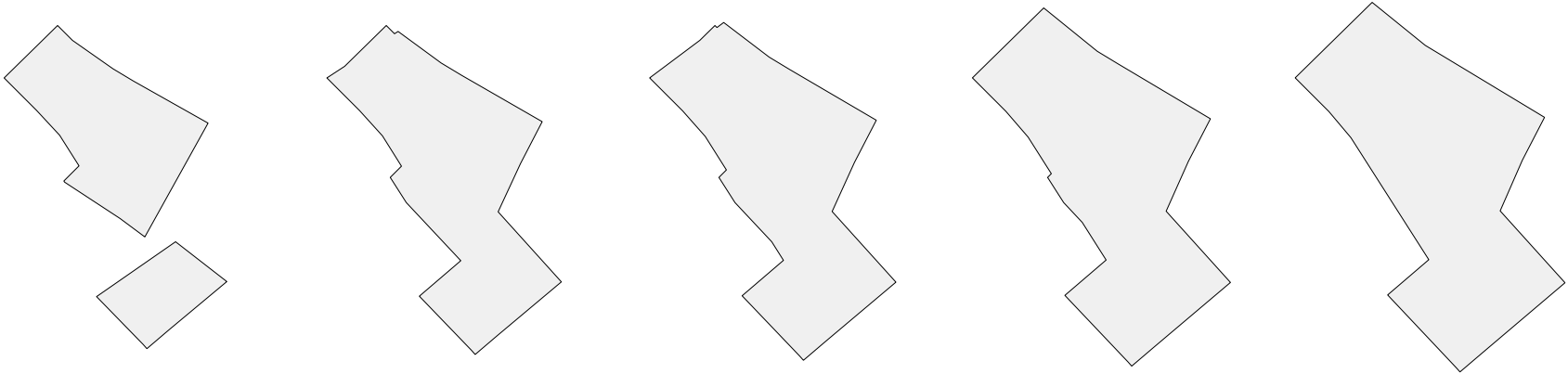


Research Problem

input

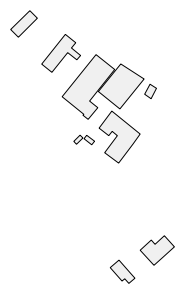


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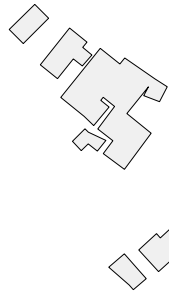


Research Problem

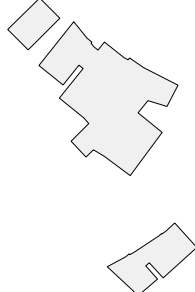
input



$t = 0$



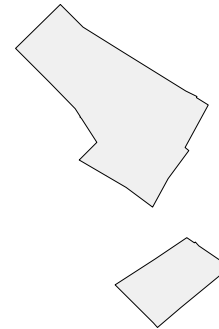
$t = 0.1$



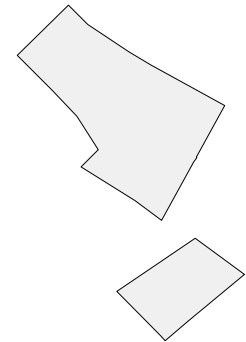
$t = 0.2$



$t = 0.3$

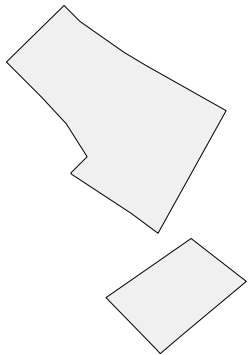


$t = 0.4$

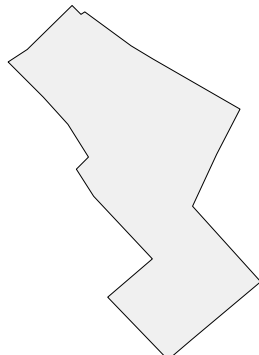


$t = 0.5$

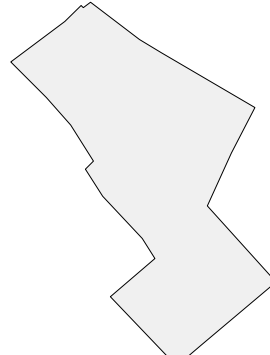
goal



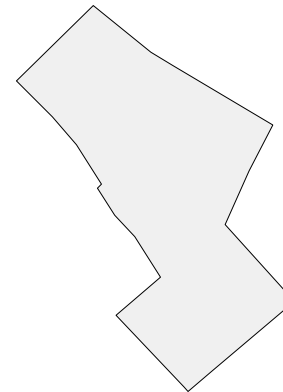
$t = 0.6$



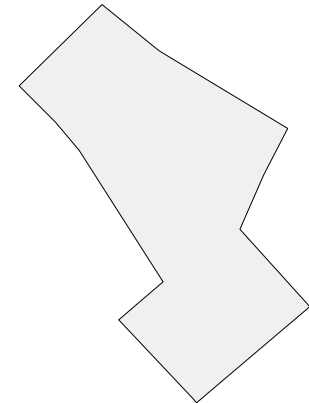
$t = 0.7$



$t = 0.8$

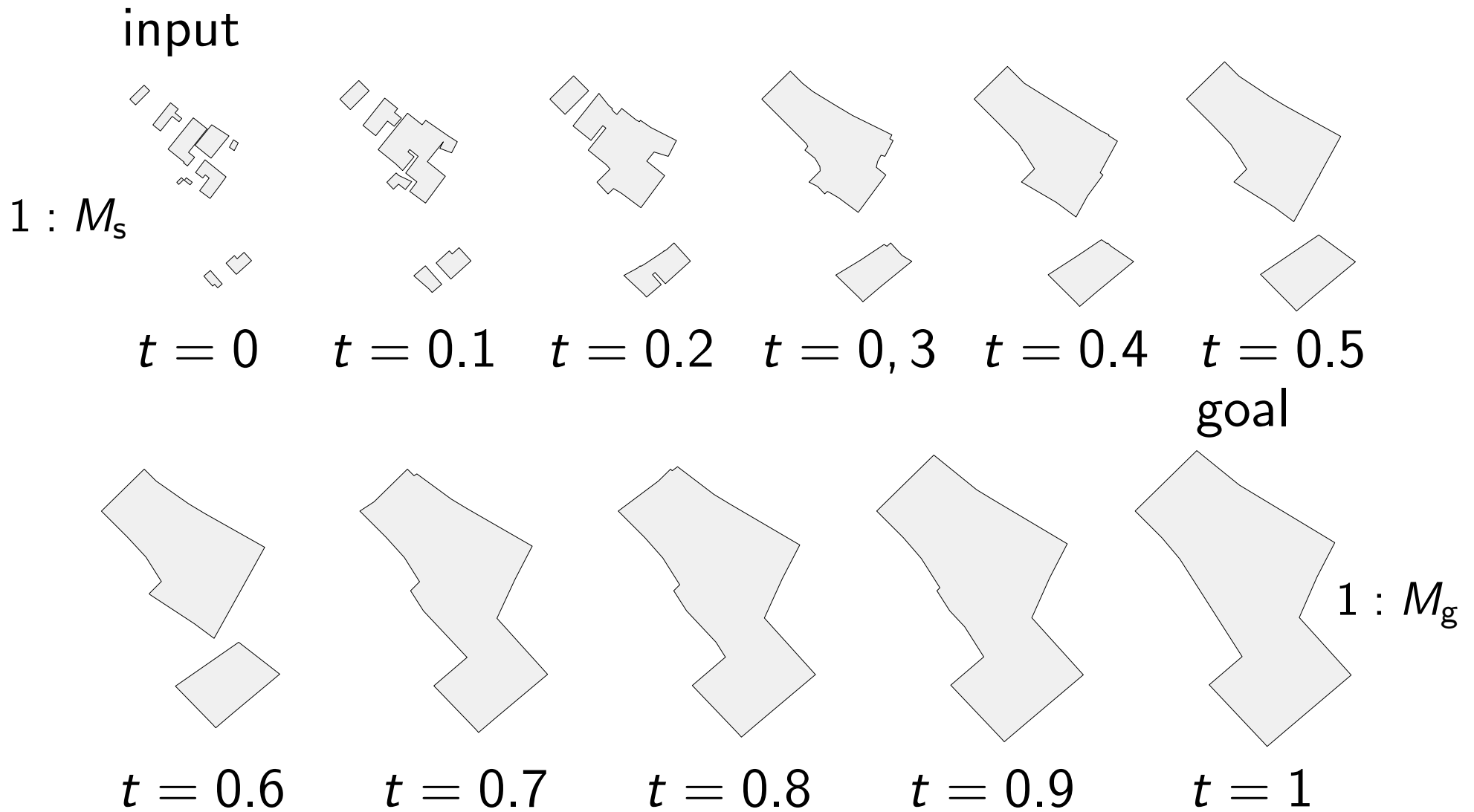


$t = 0.9$

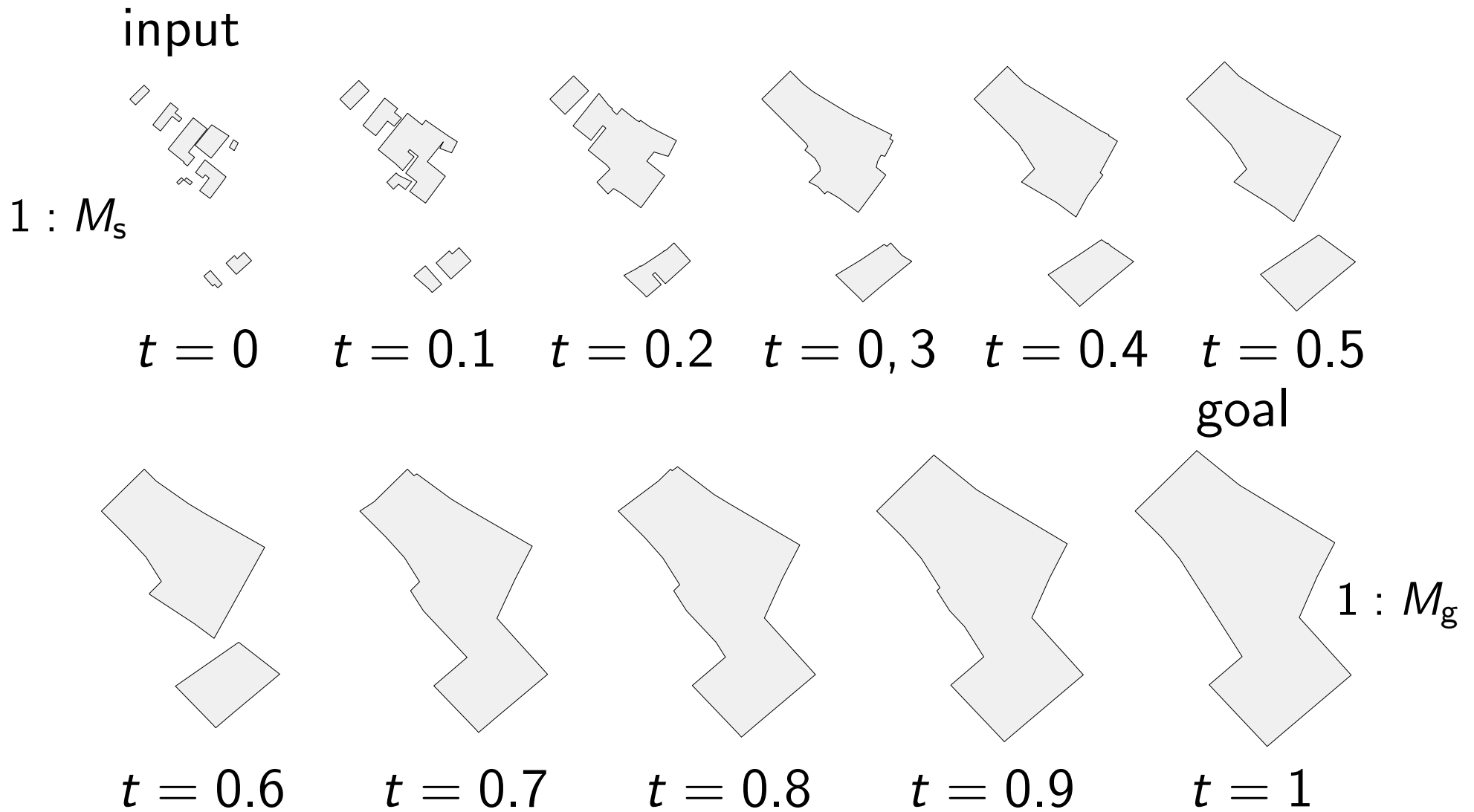


$t = 1$

Research Problem



Research Problem

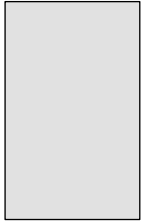


$$M_t = M_s + t \cdot (M_g - M_s)$$

Outline

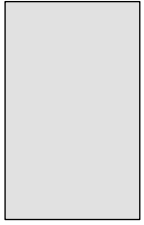
- Introduction
- Methodology
- Case Study
- Concluding Remarks

Three Join Types of Buffering

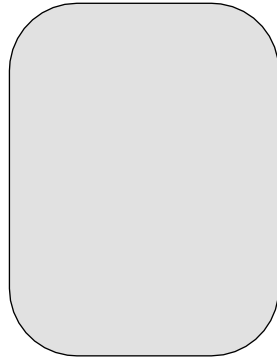


rectangle

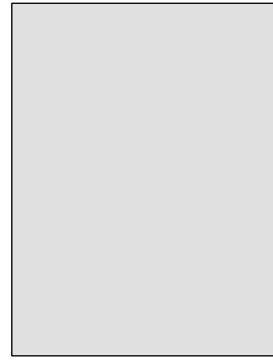
Three Join Types of Buffering



rectangle



round

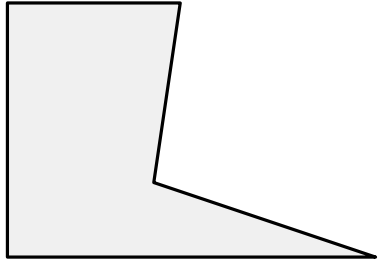


miter

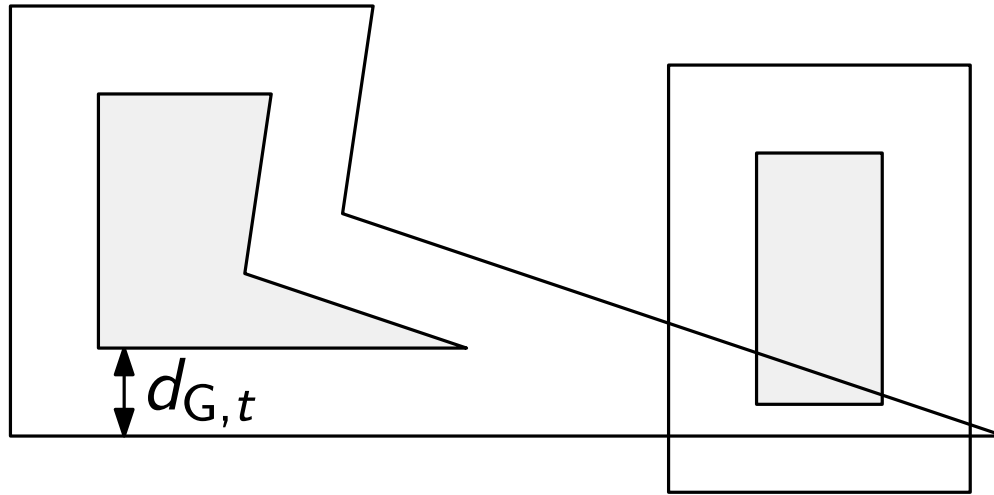


square

Growing Buildings by Buffering

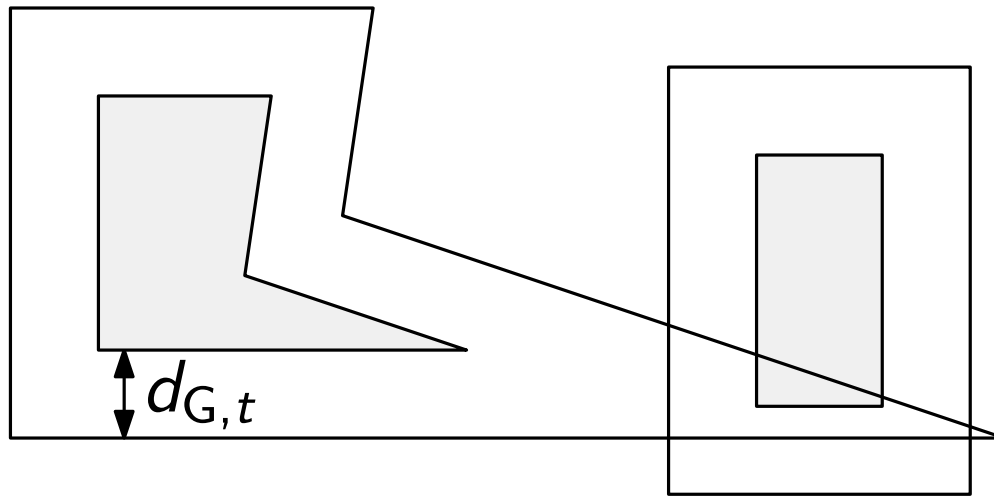


Growing Buildings by Buffering



buffering using miter joins to keep right angles

Growing Buildings by Buffering

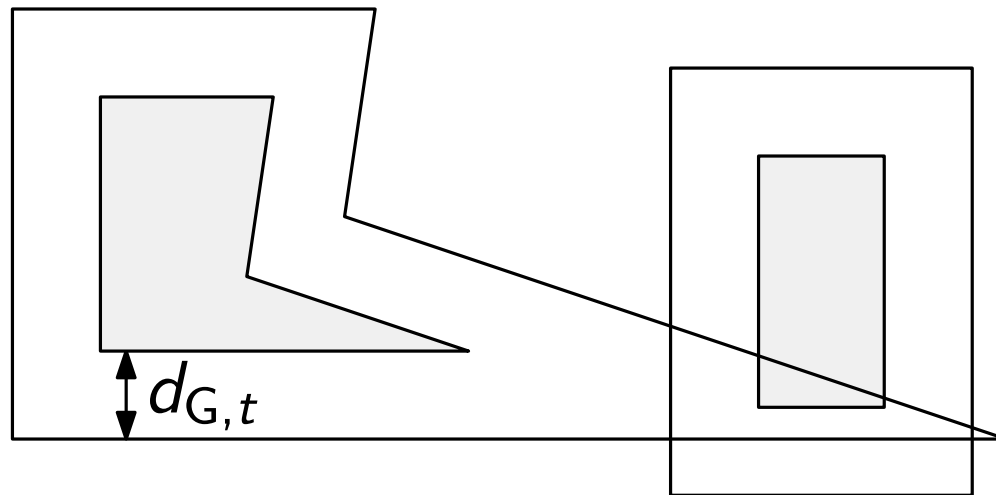


$$d_{G,t} = t \cdot d_G$$

d_G : input

buffering using miter joins to keep **right angles**

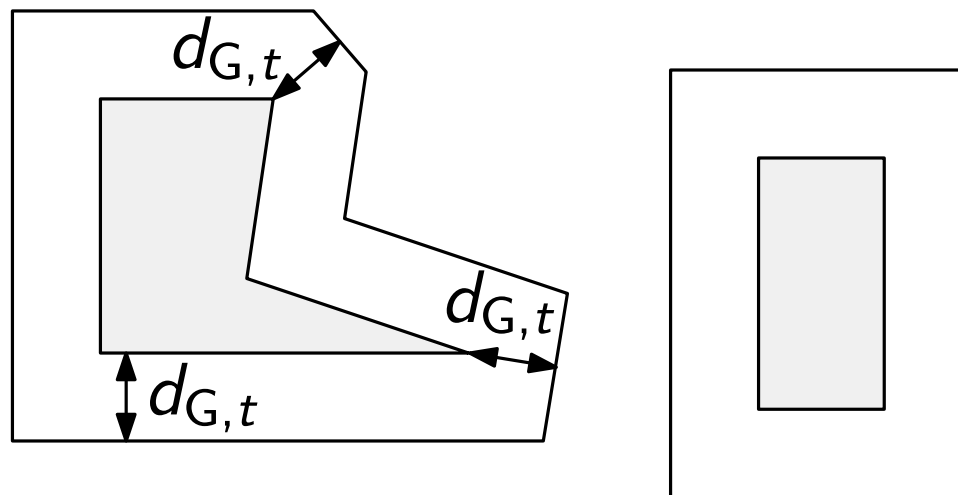
Growing Buildings by Buffering



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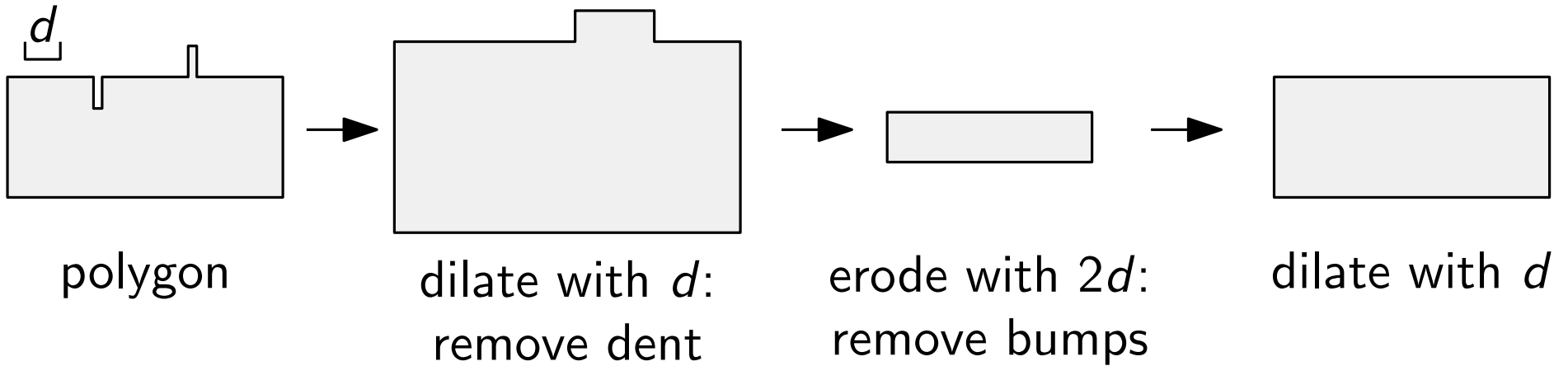
buffering using miter joins to keep **right angles**



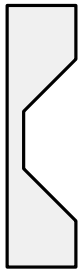
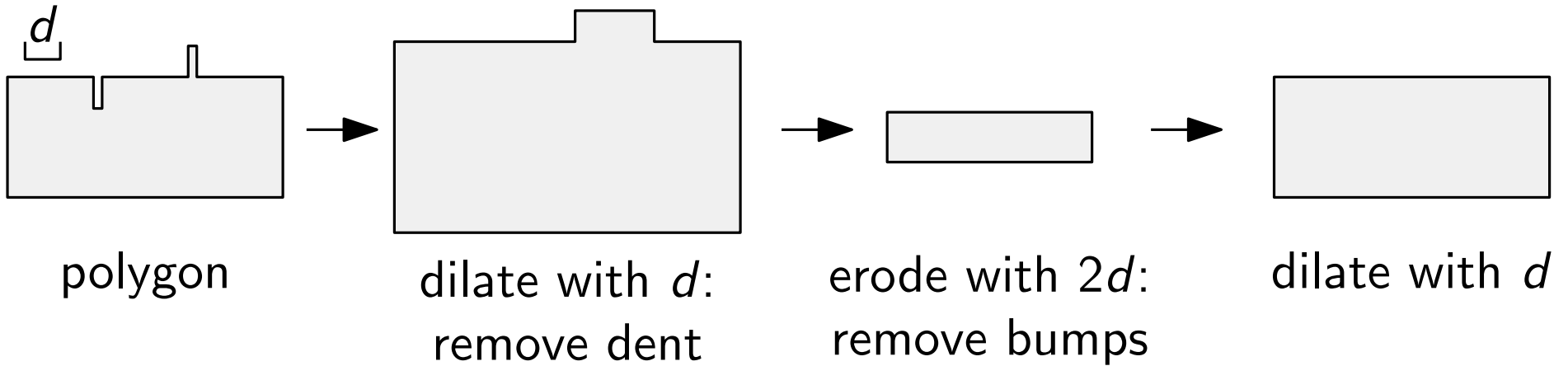
squaring if spikes are too long:

distance larger than $\alpha d_{G,t}$, where we set $\alpha = 1.5$

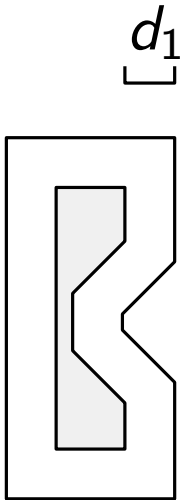
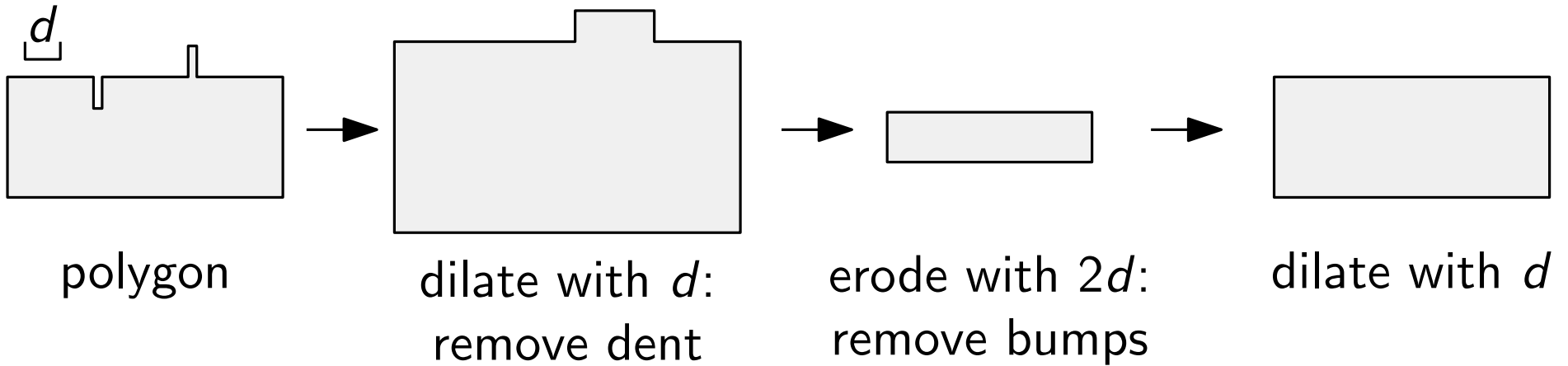
Simplifying Based on Dilation and Erosion



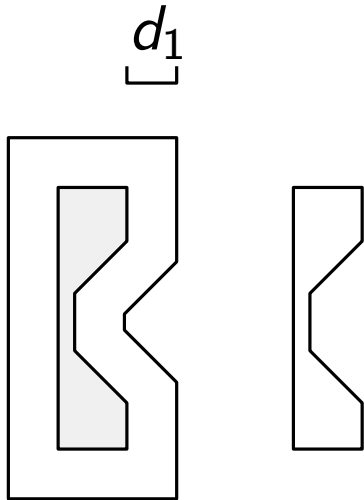
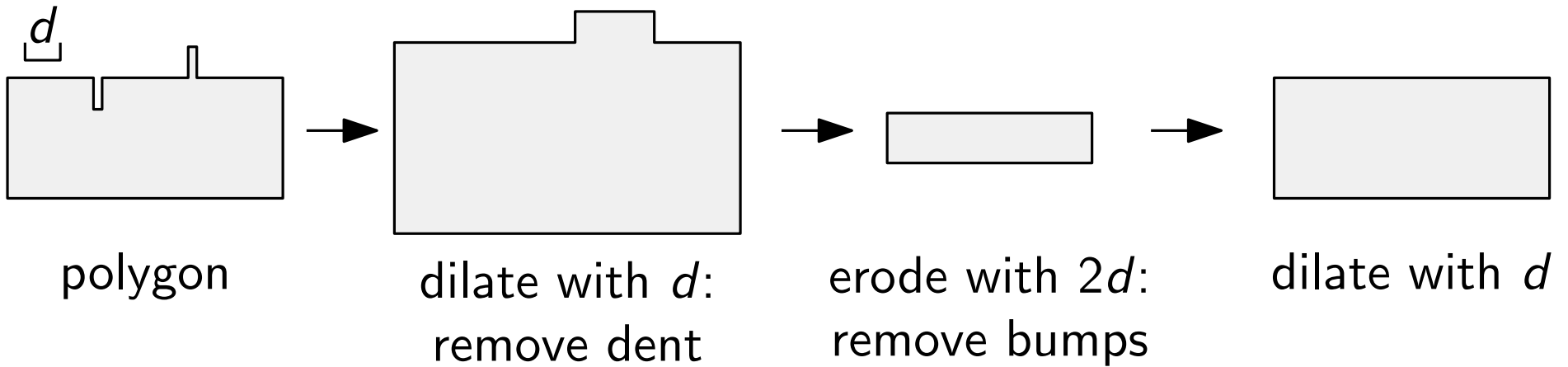
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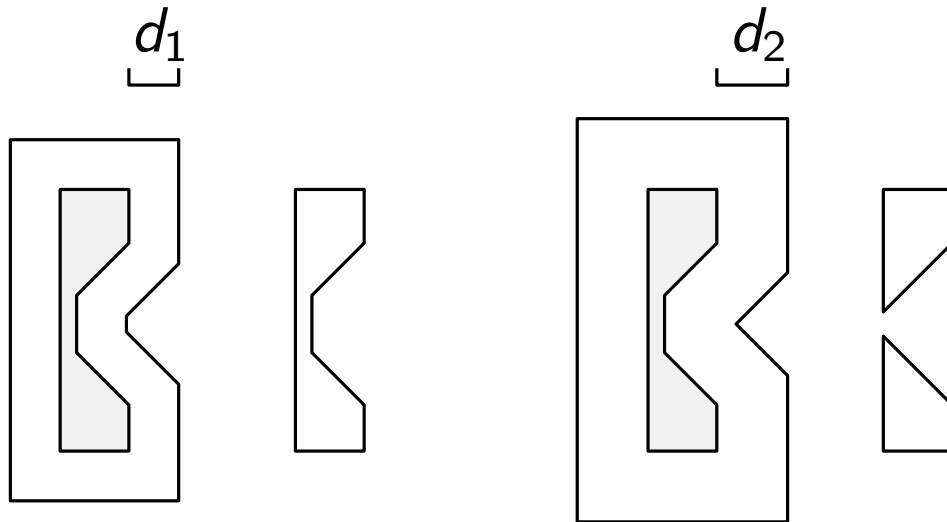
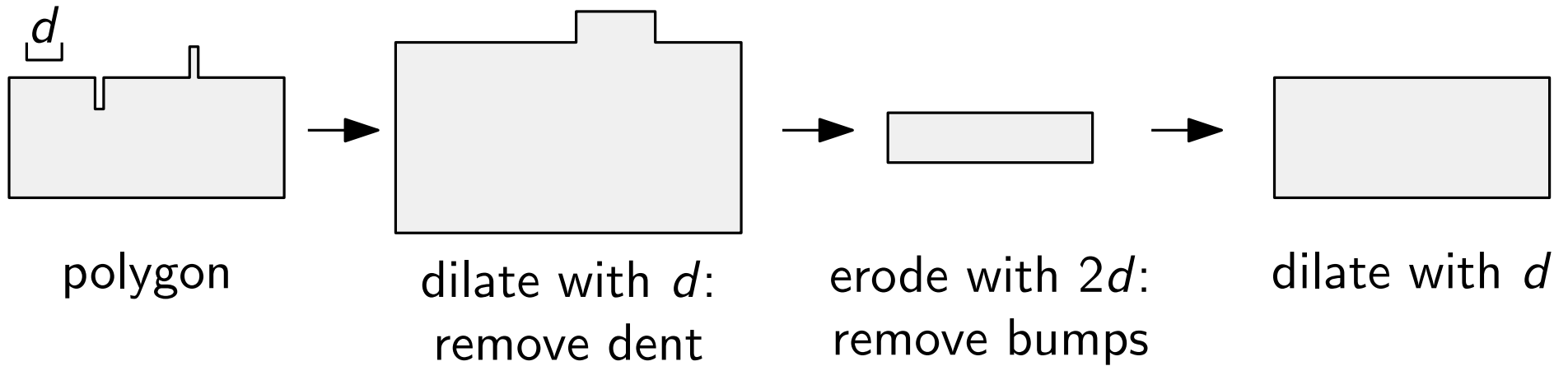
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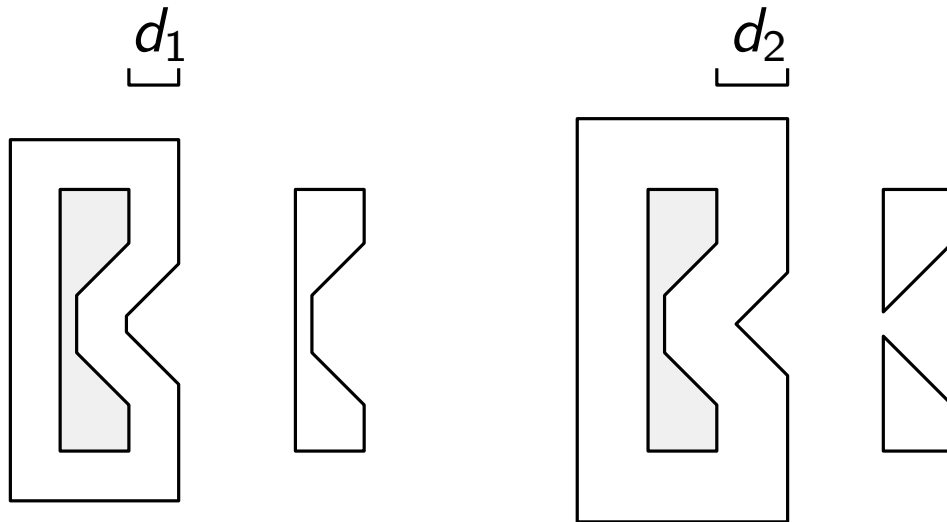
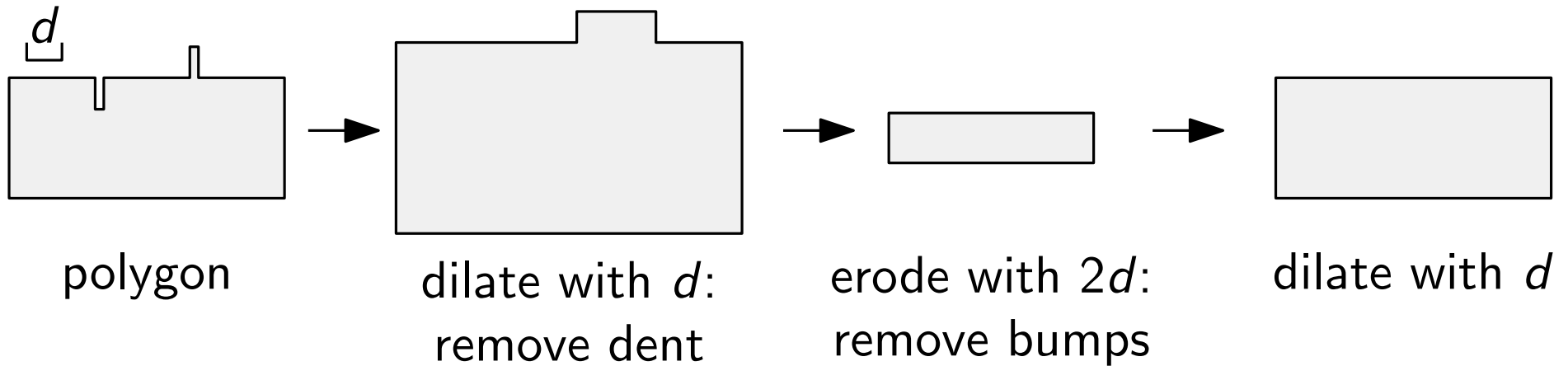
Simplifying Based on Dilation and Erosion



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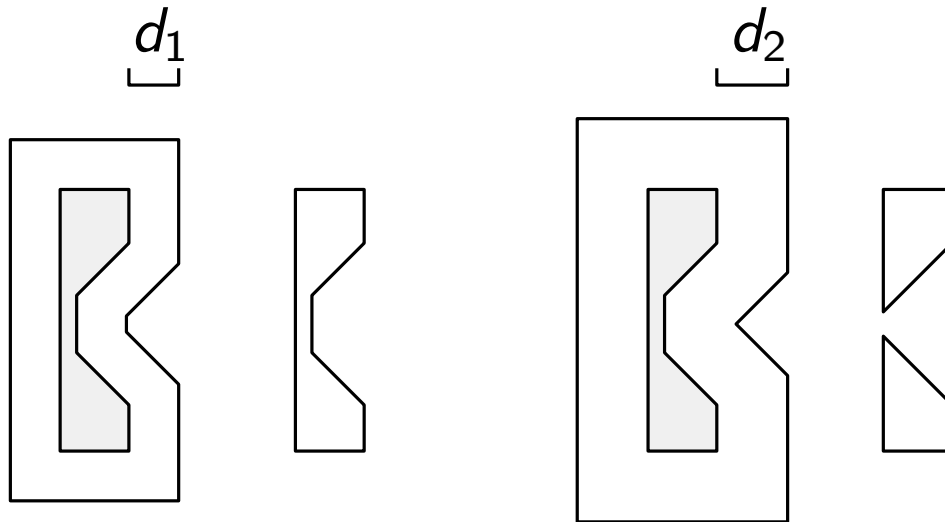
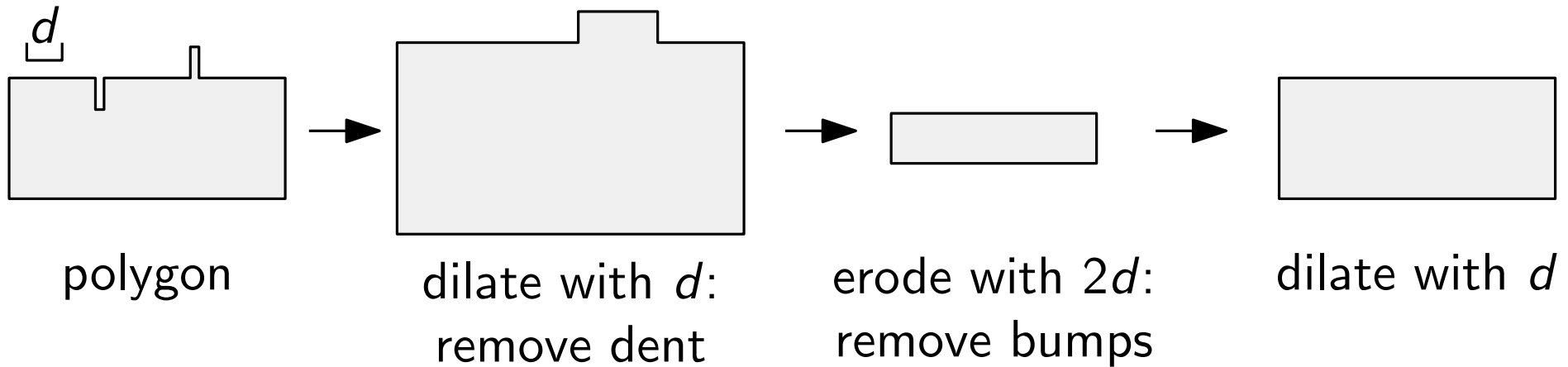
Simplifying Based on Dilation and Erosion



$$d_{E,t} = t \cdot \frac{\ell}{2} M_g$$

$$\ell = 0.3 \text{ mm}$$

Simplifying Based on Dilation and Erosion



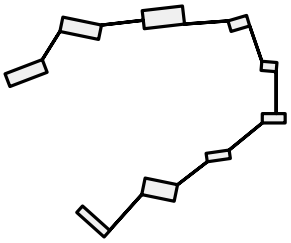
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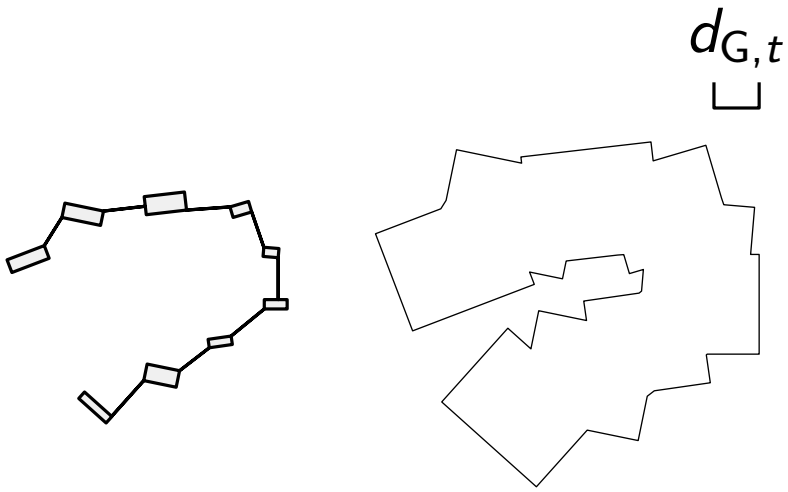
avoid breaking:

$$d_{D,t} = \frac{d_{G,t} - d_{E,t}}{\alpha - 1}$$

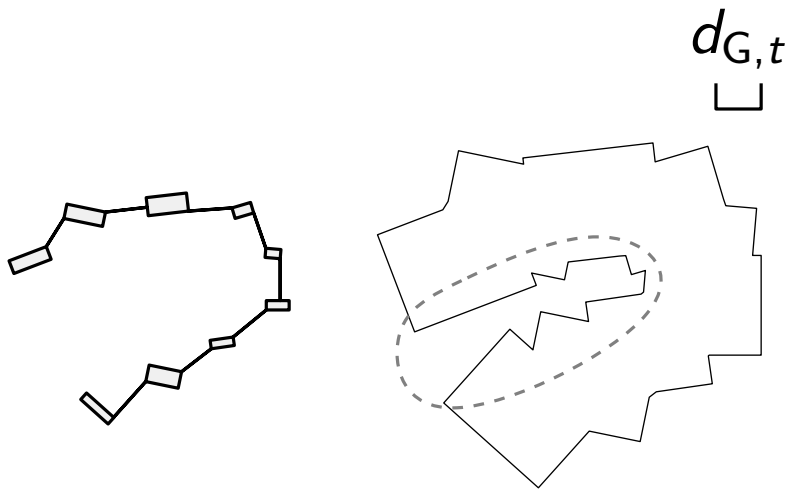
A “Bay” Removed by Dilation



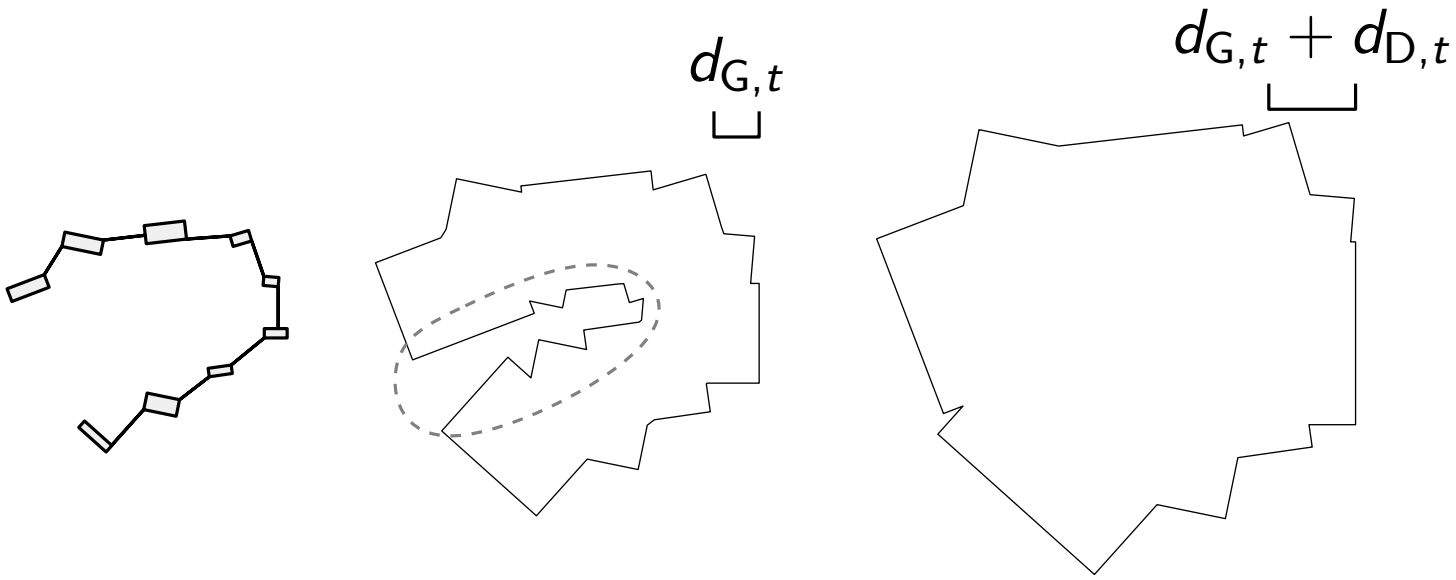
A “Bay” Removed by Dilation



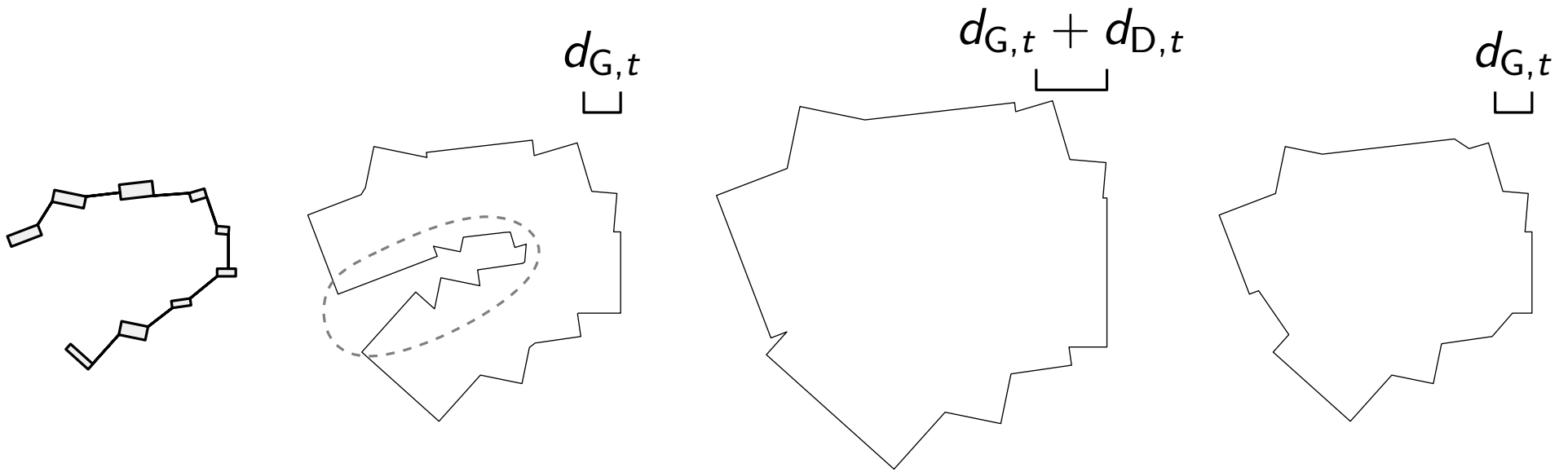
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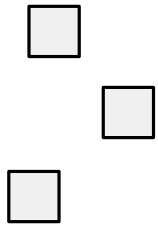


A “Bay” Removed by Dilation



Aggregating Buildings by Adding Bridges

- Bridges and buildings constitute a **minimum spanning tree (MST)**

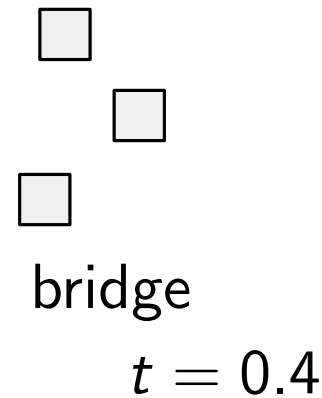
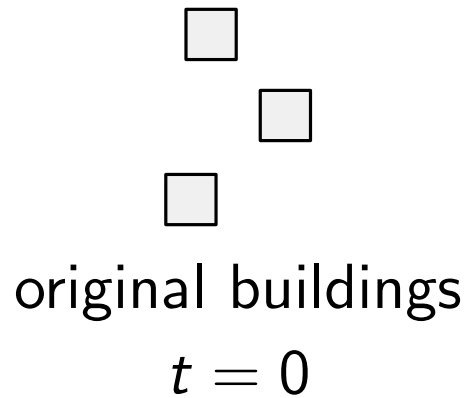


original buildings

$t = 0$

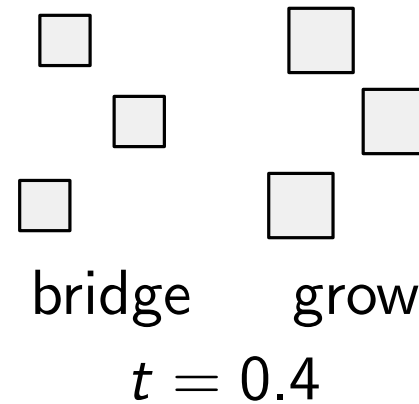
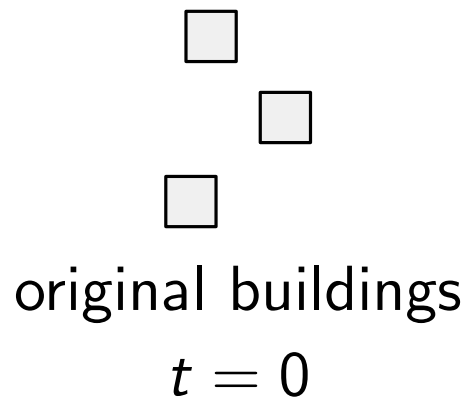
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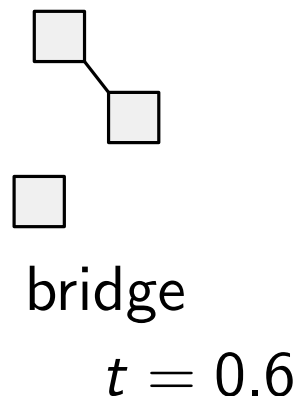
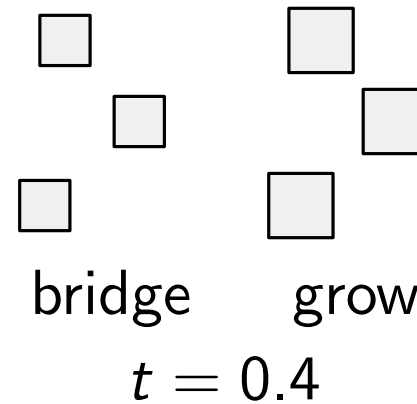
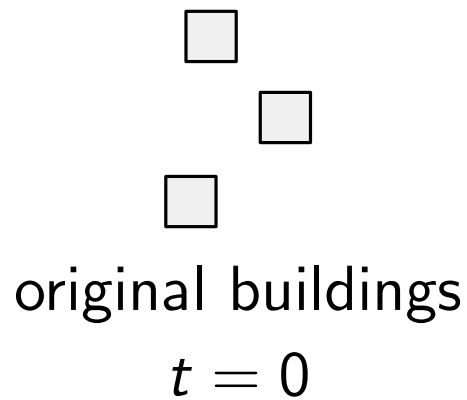
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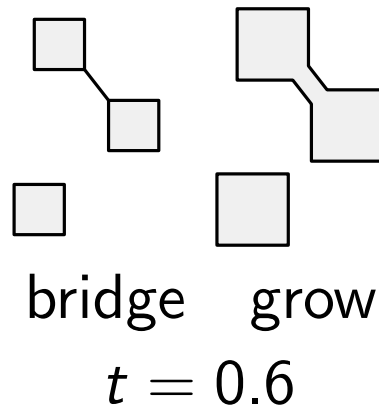
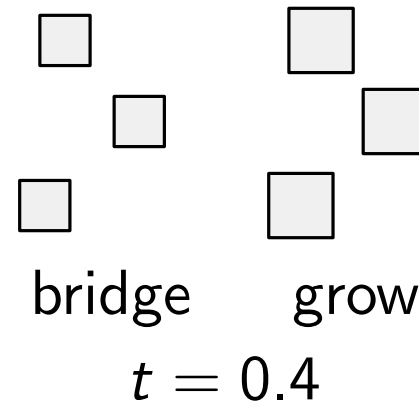
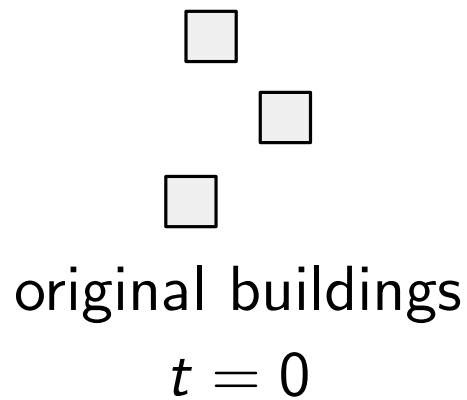
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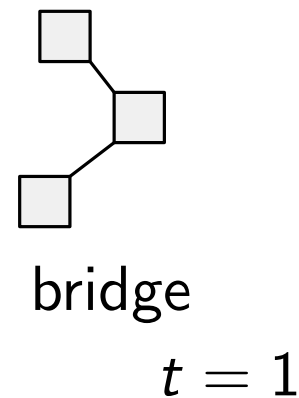
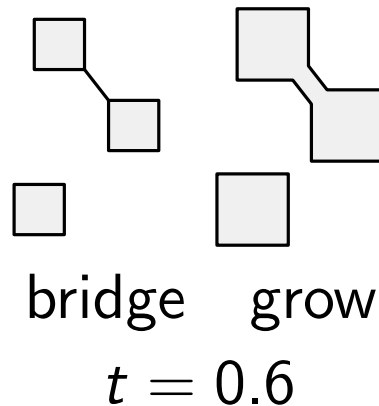
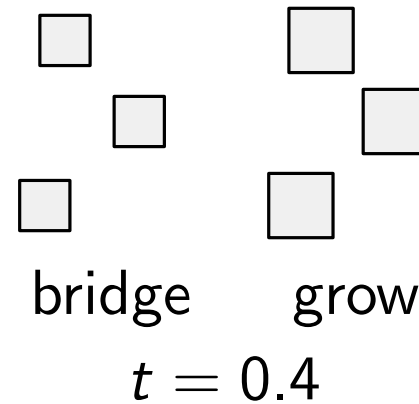
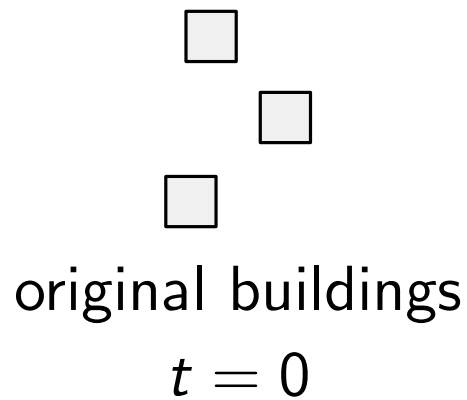
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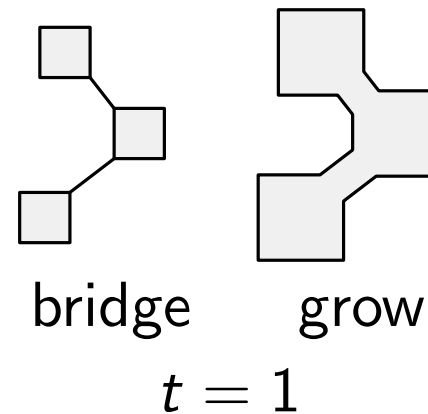
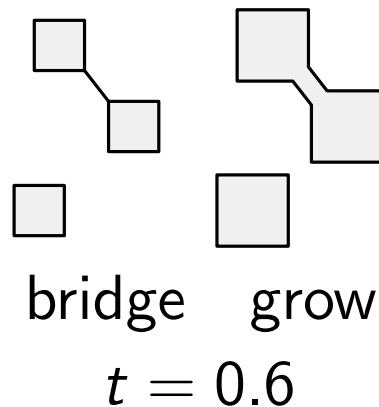
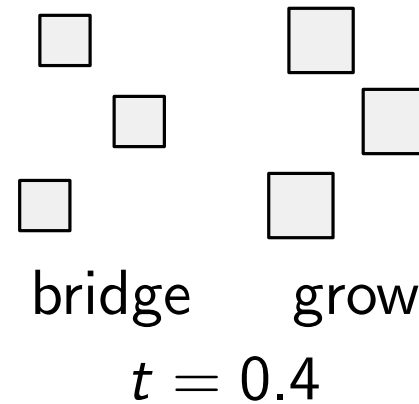
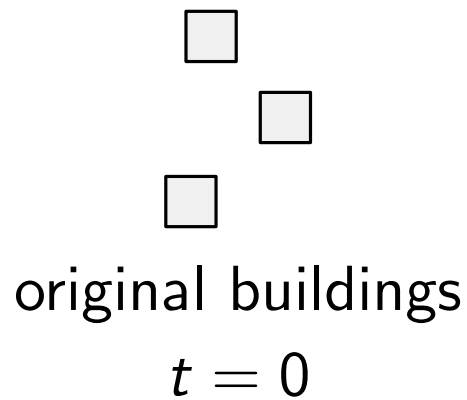
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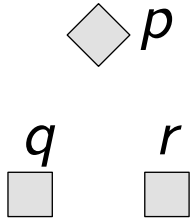


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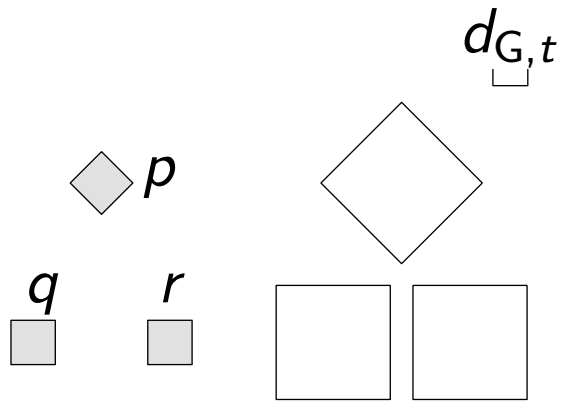
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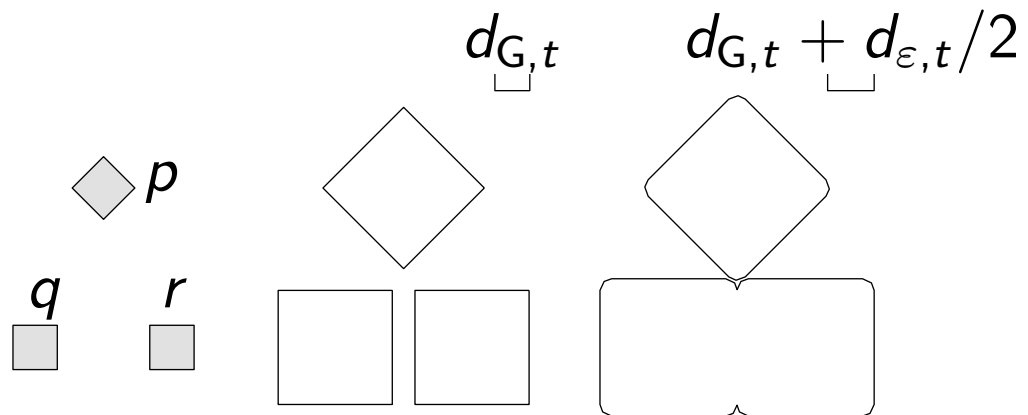
Iteratively Aggregating



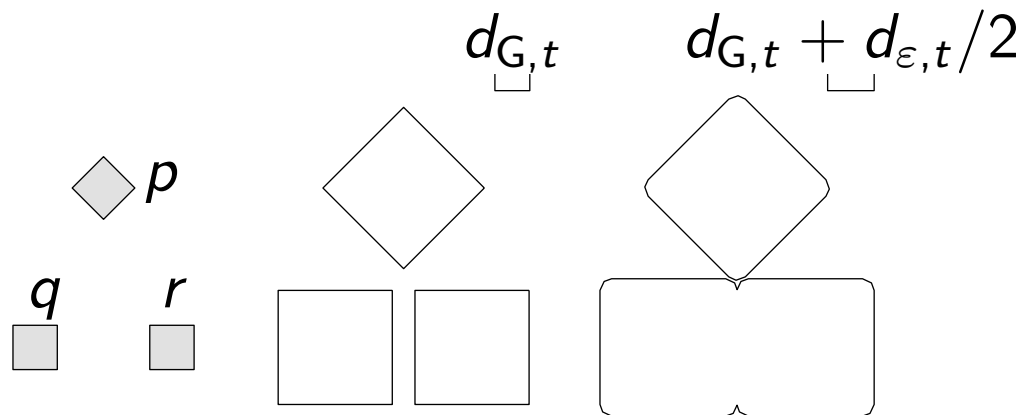
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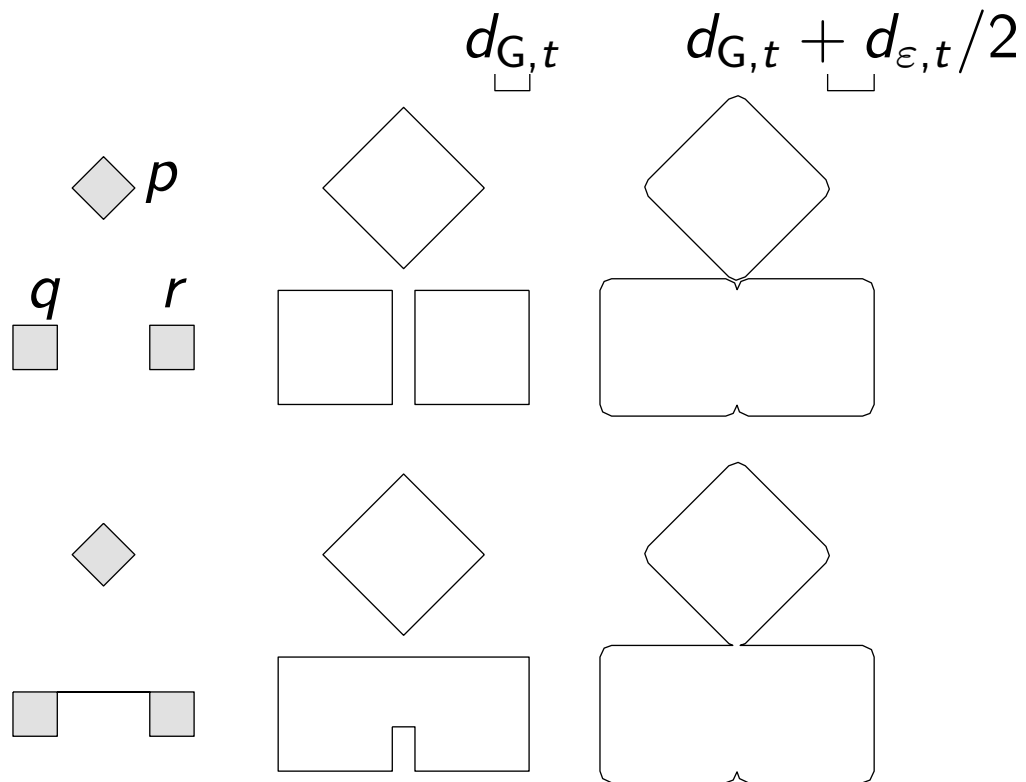


Iteratively Aggregating



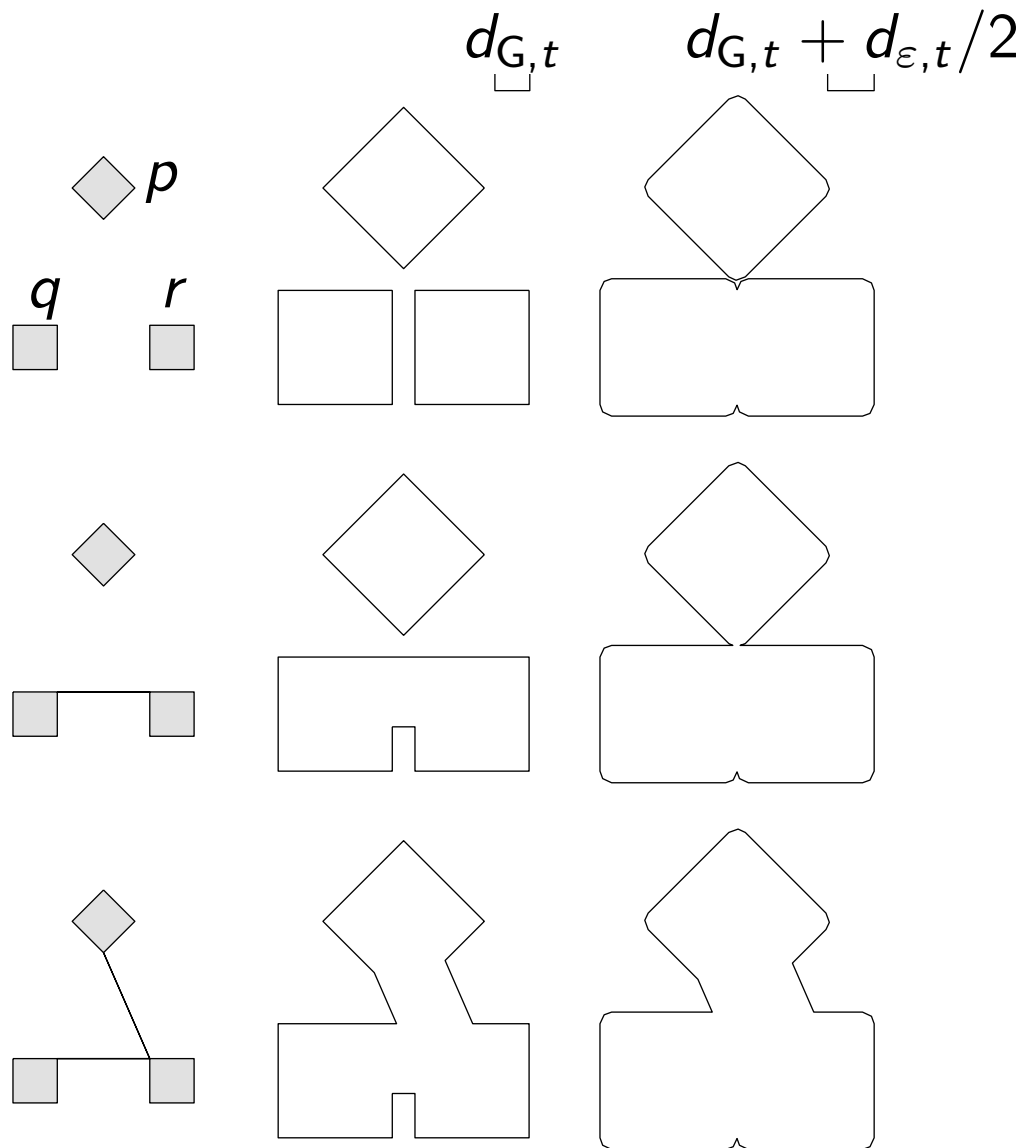
two buildings are too close:
distance $< d_{\varepsilon,t}$

Iteratively Aggregating



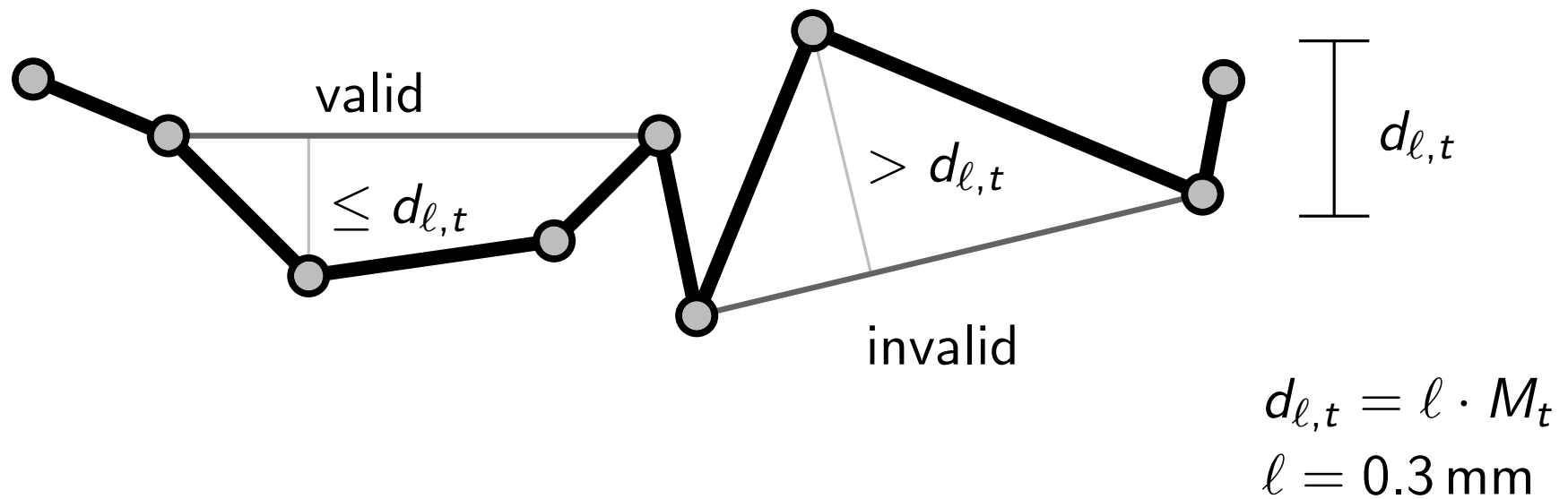
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distance $< d_{\epsilon,t}$

Iteratively Aggregating



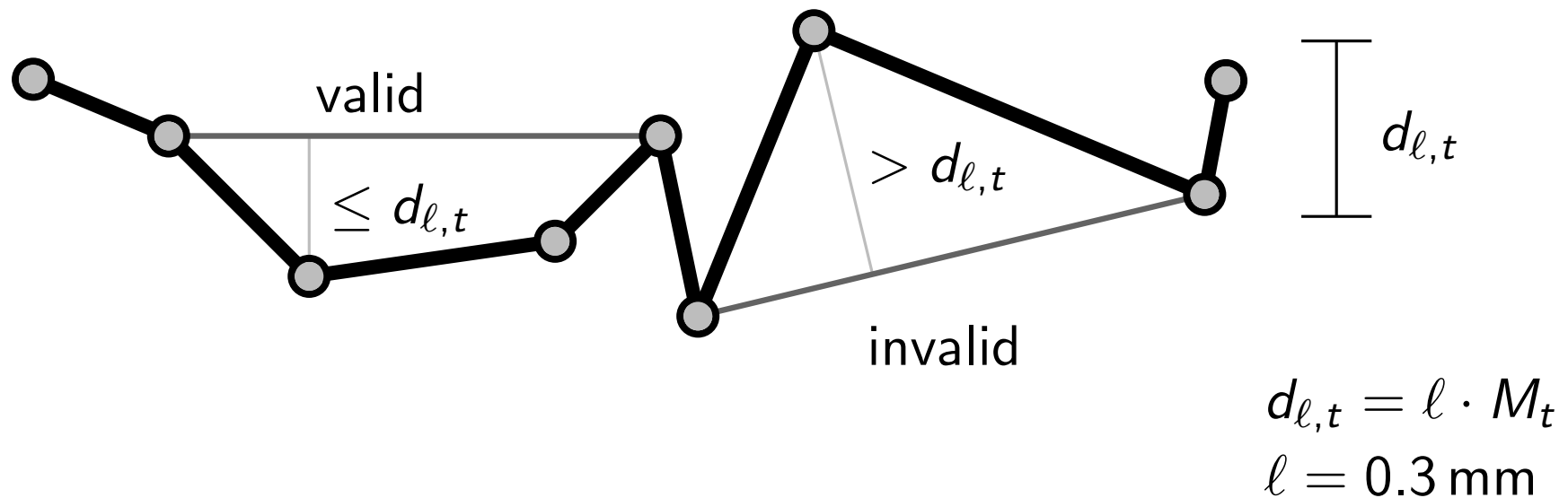
Simplifying Based on Imai-Iri Algorithm

- Finding all valid shortcuts



Simplifying Based on Imai-Iri Algorithm

- Finding all valid shortcuts
- Finding a sequence of valid shortcuts with the **least number** using **breadth-first search**



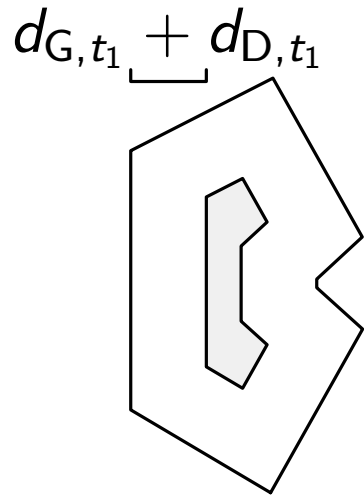
Producing Intermediate-Scale maps

A building may **shrink** because of **erosion**



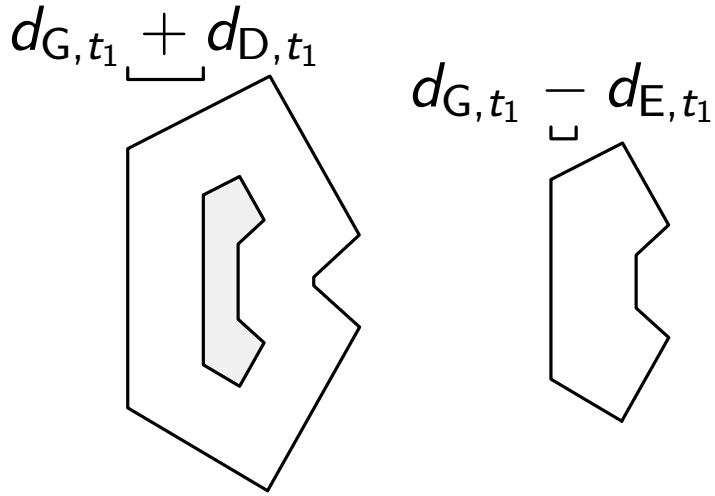
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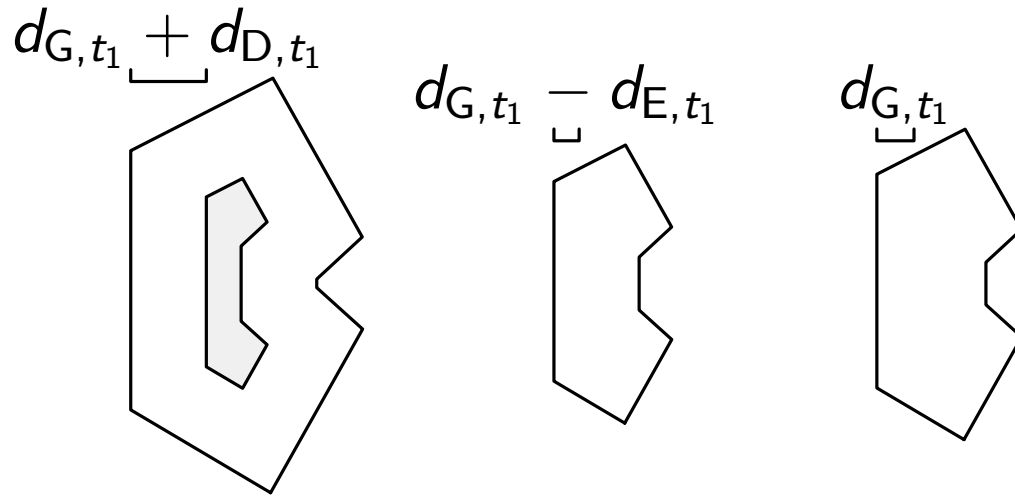
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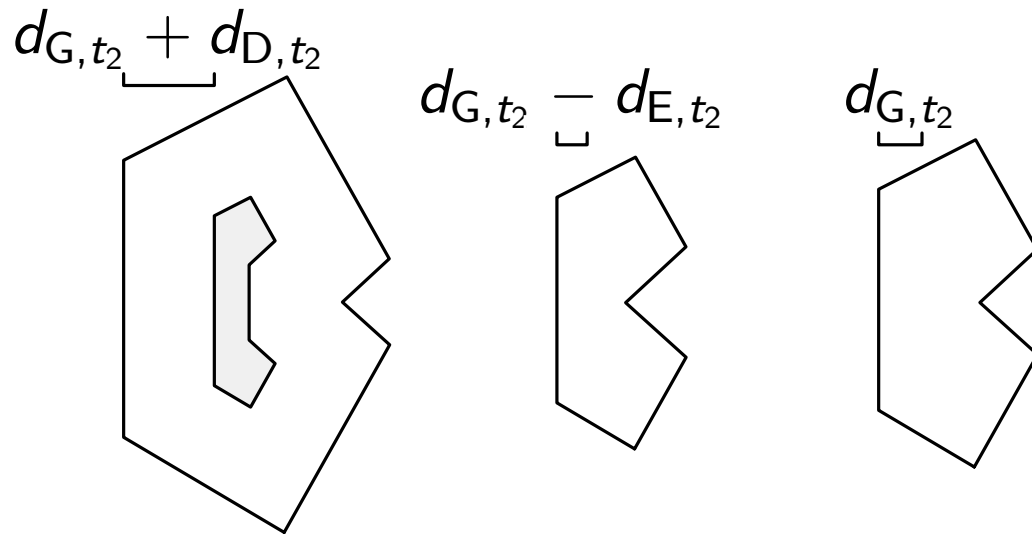
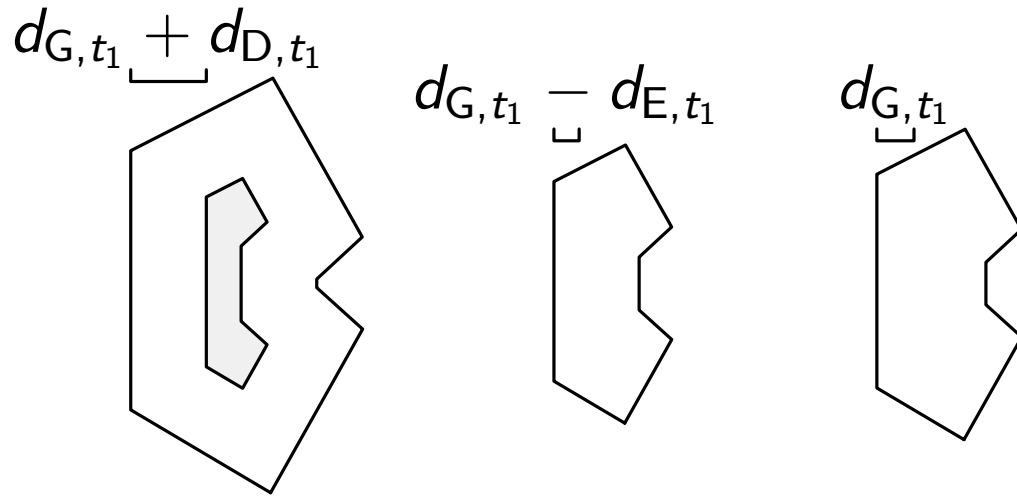
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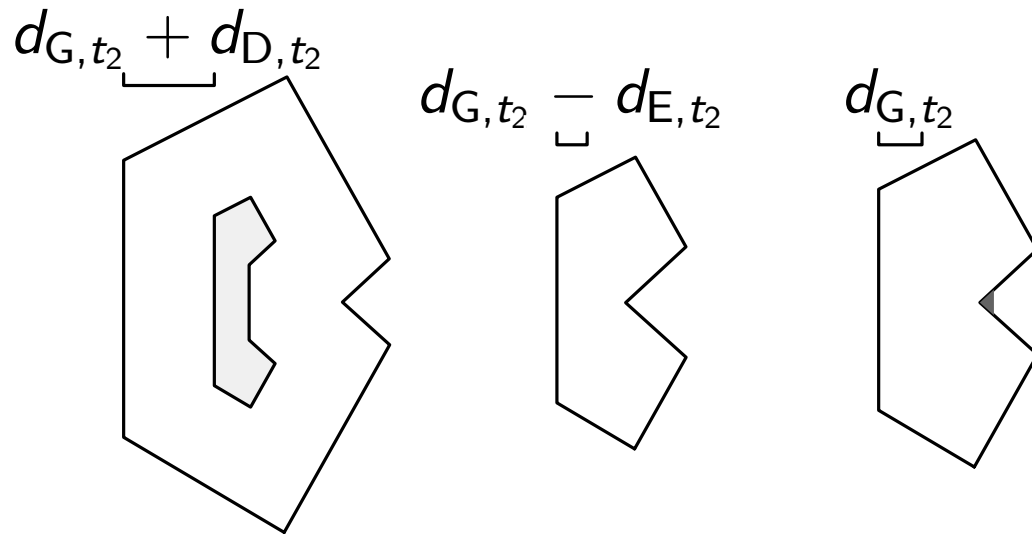
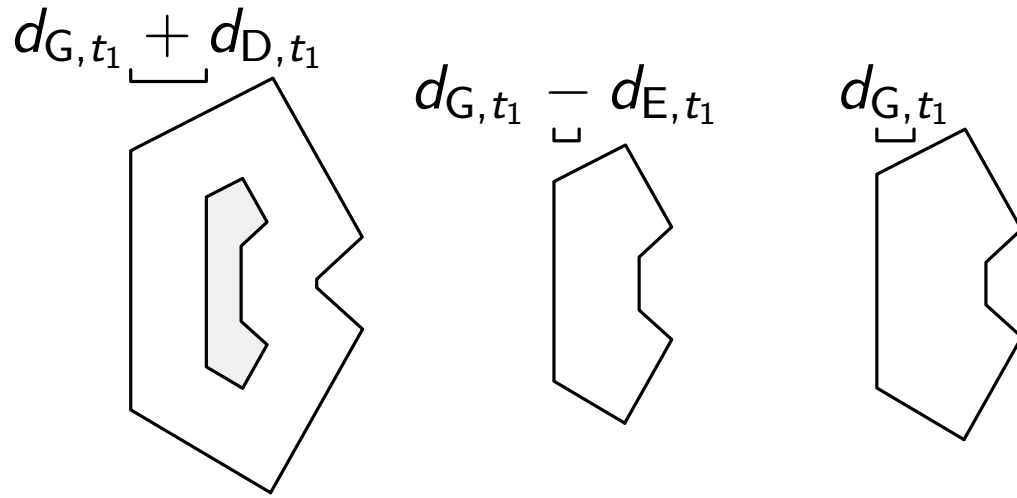
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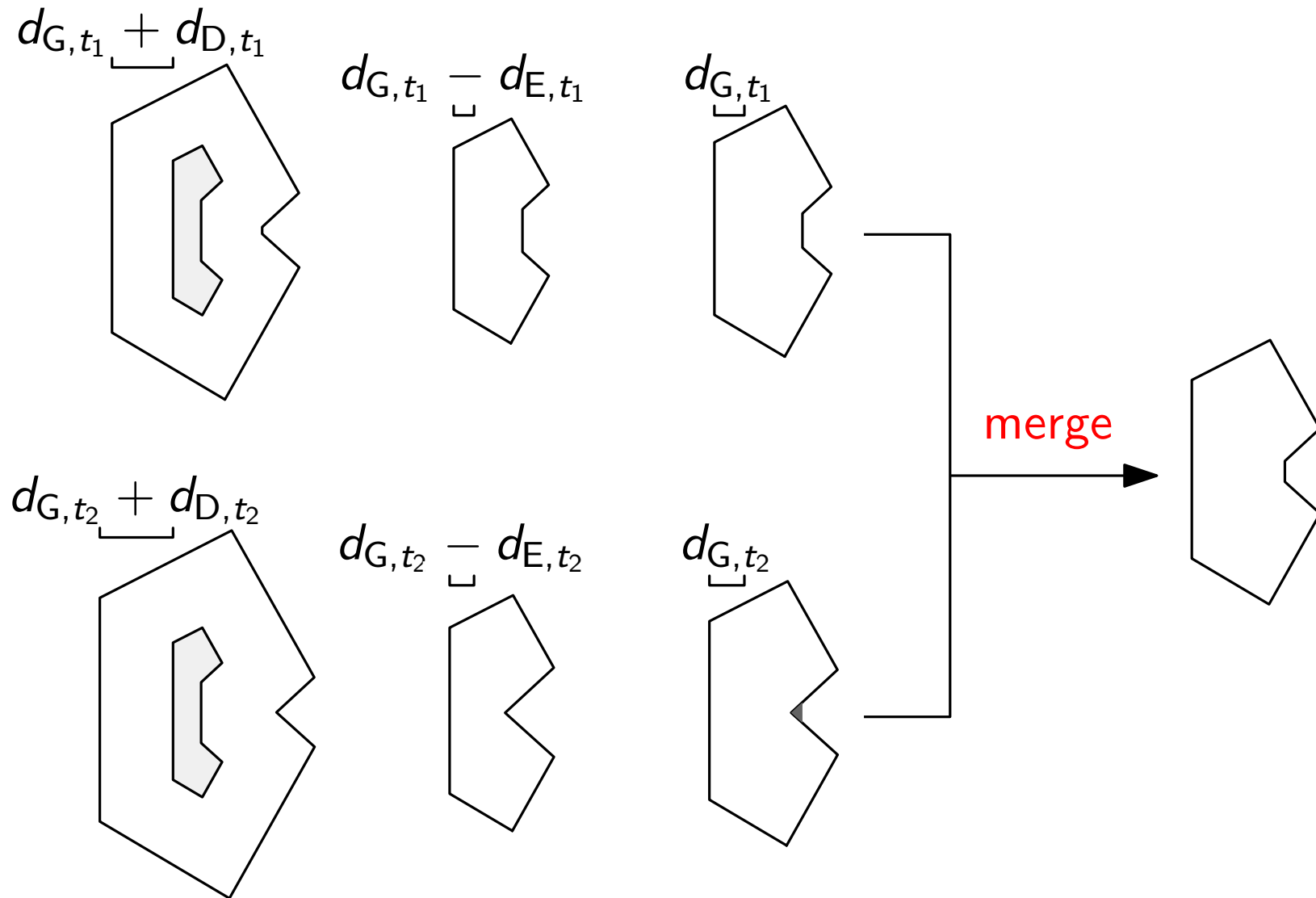
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Producing Intermediate-Scale maps

A building may **shrink** because of **line simplification**

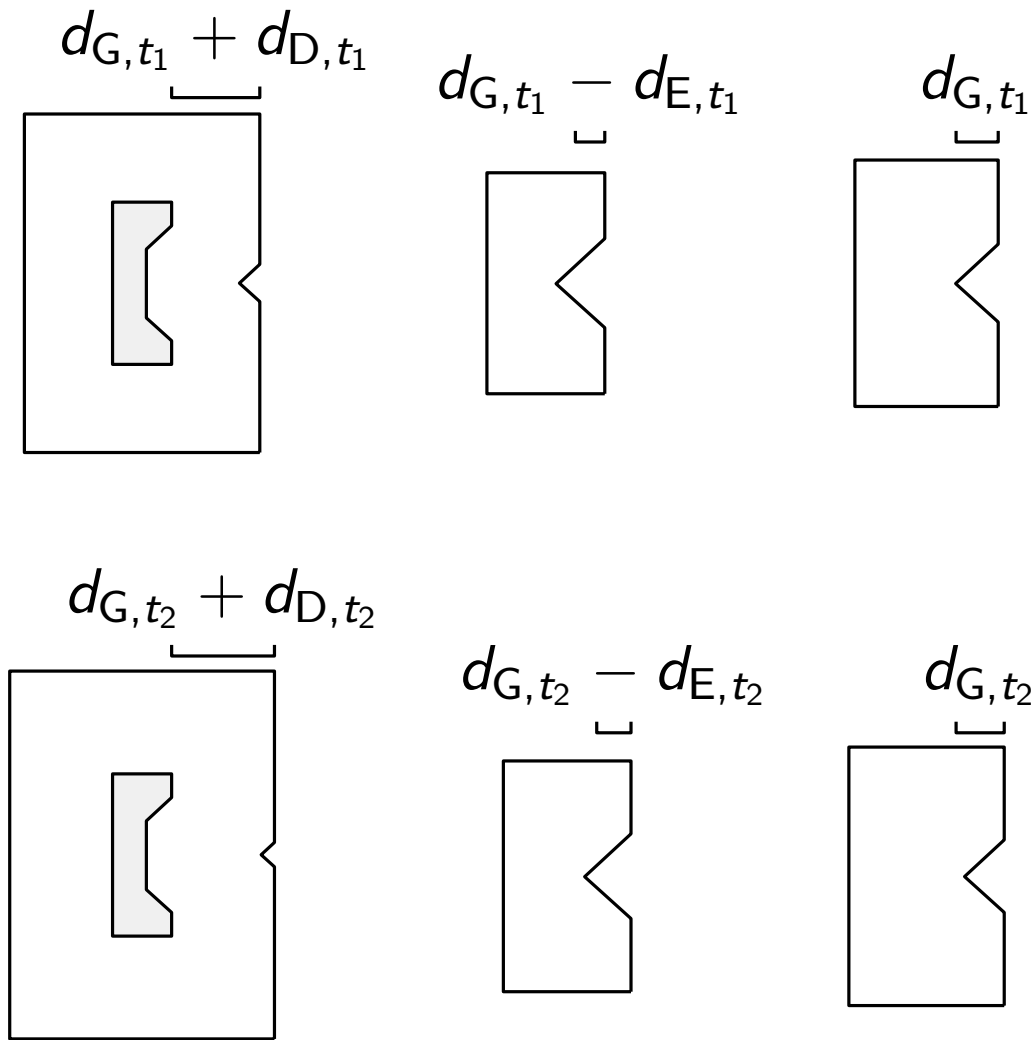
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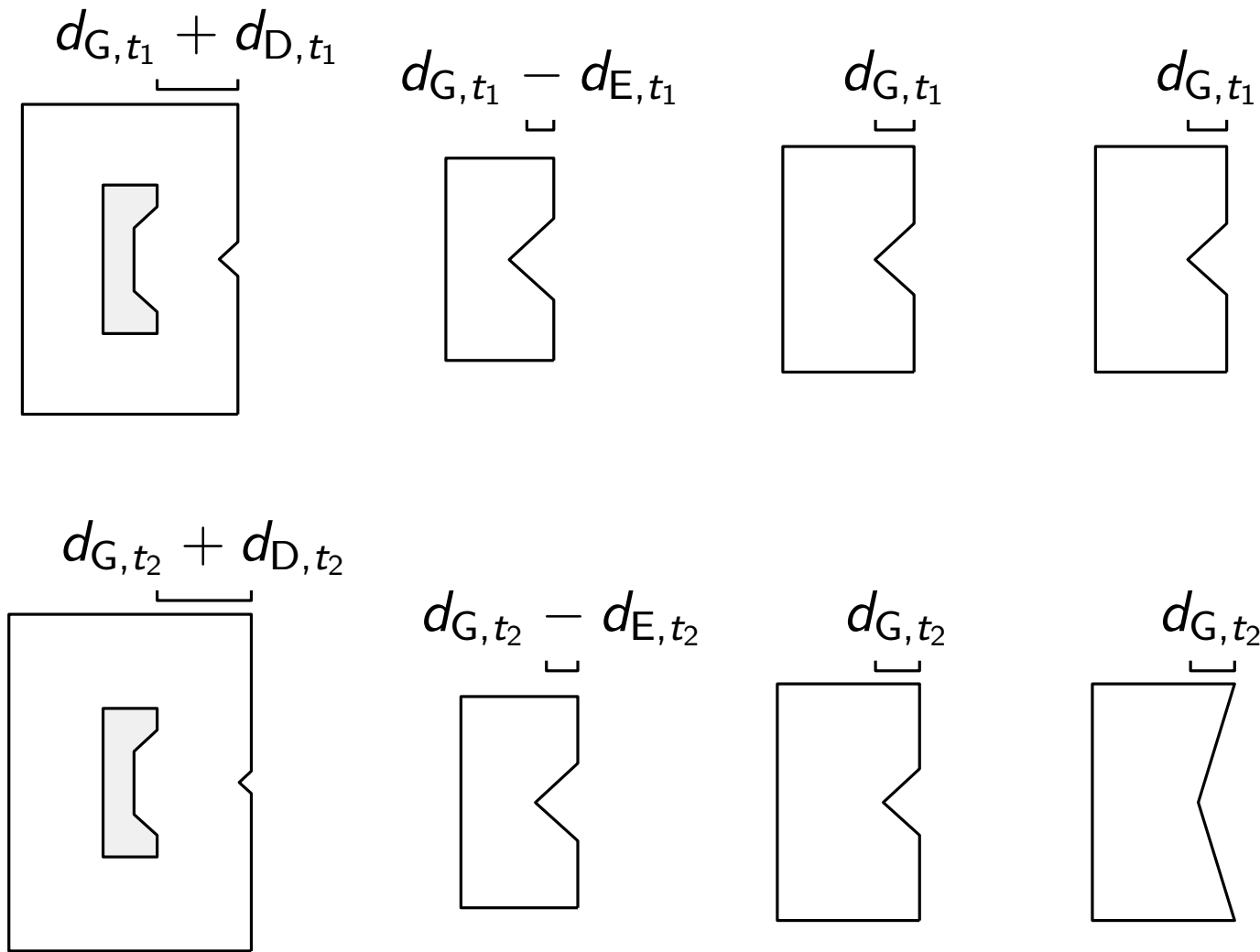
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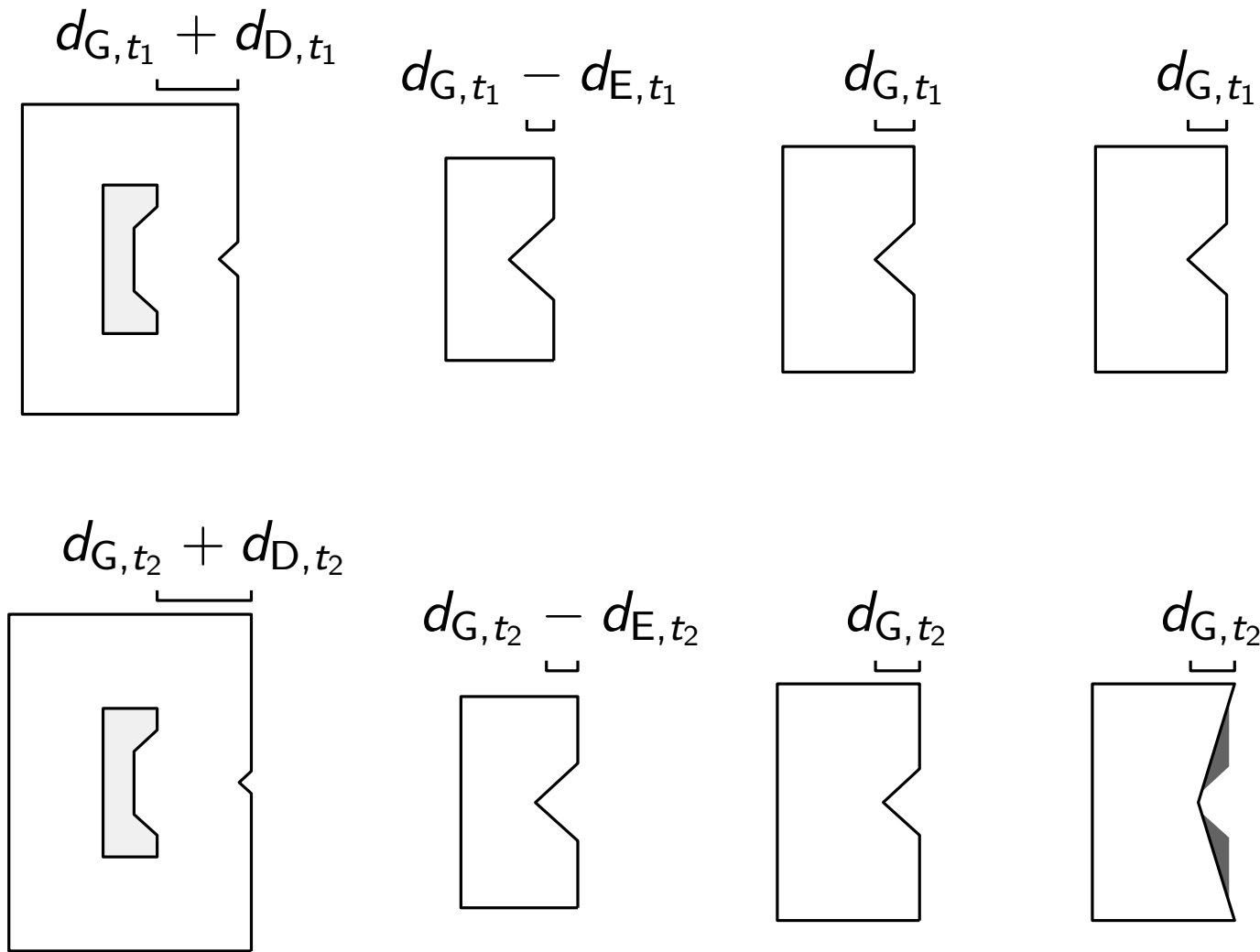
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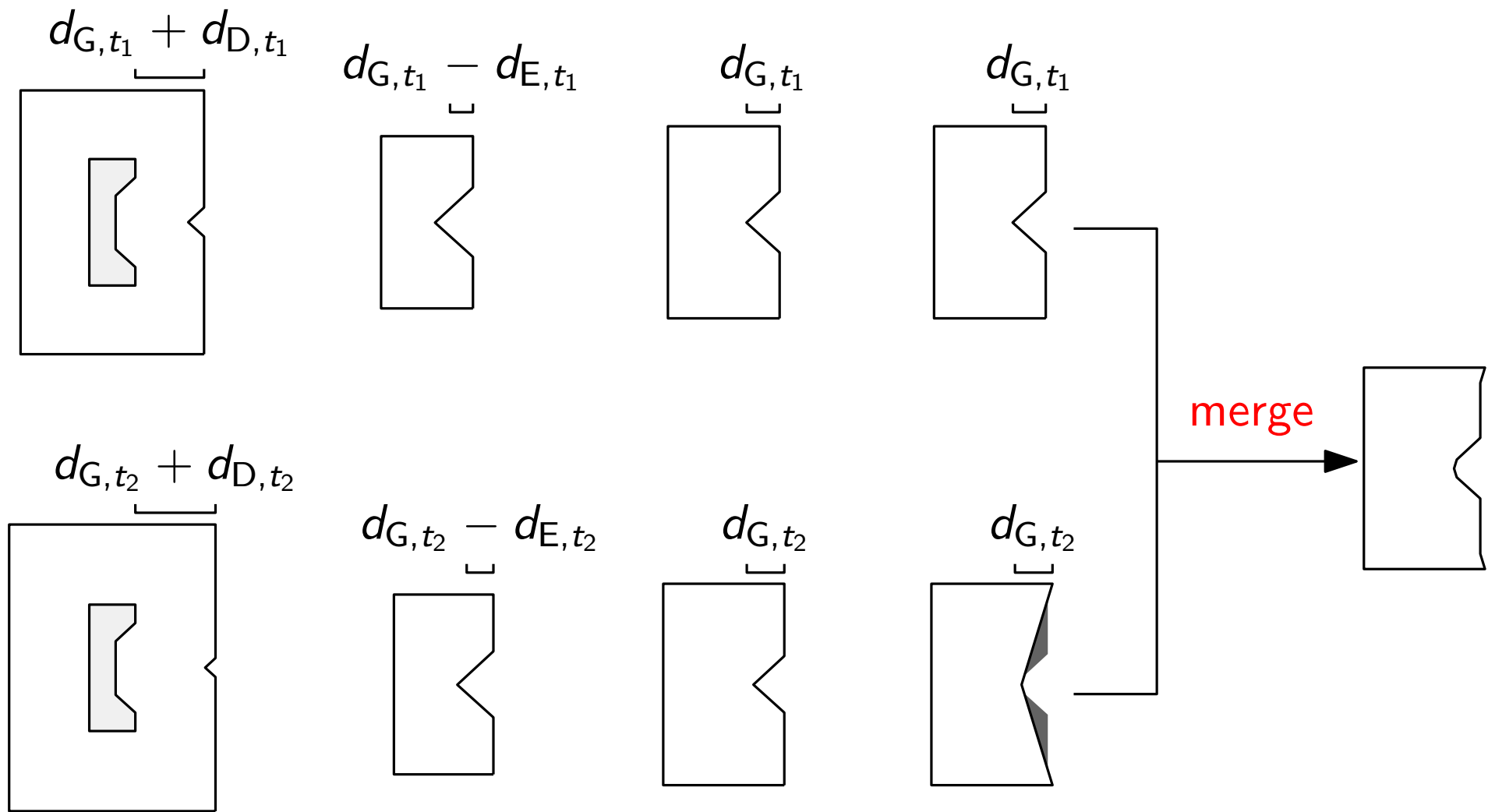
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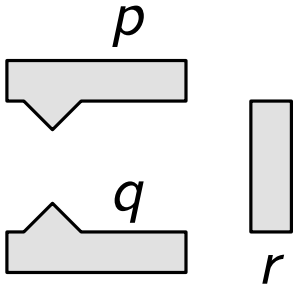


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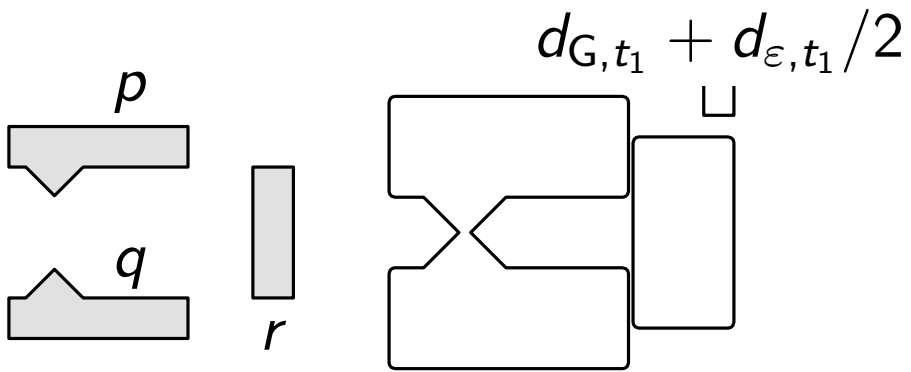
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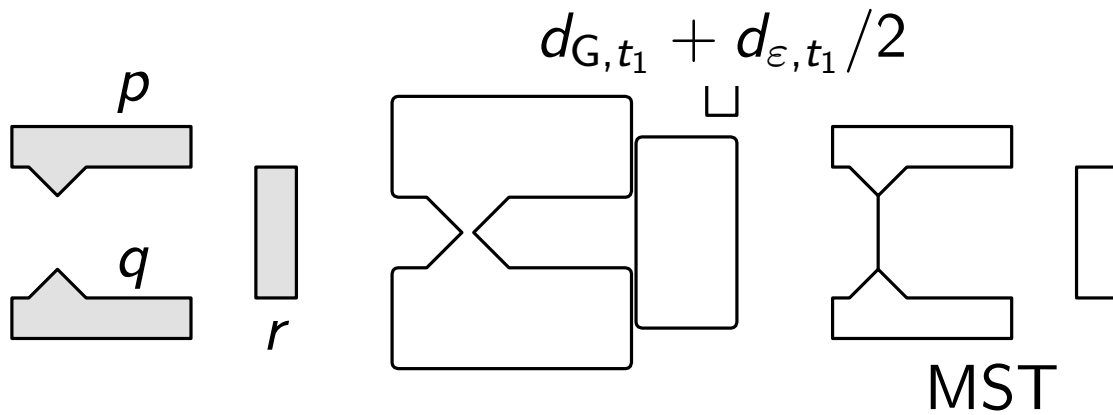
Merging Avoiding Shriking Bridges



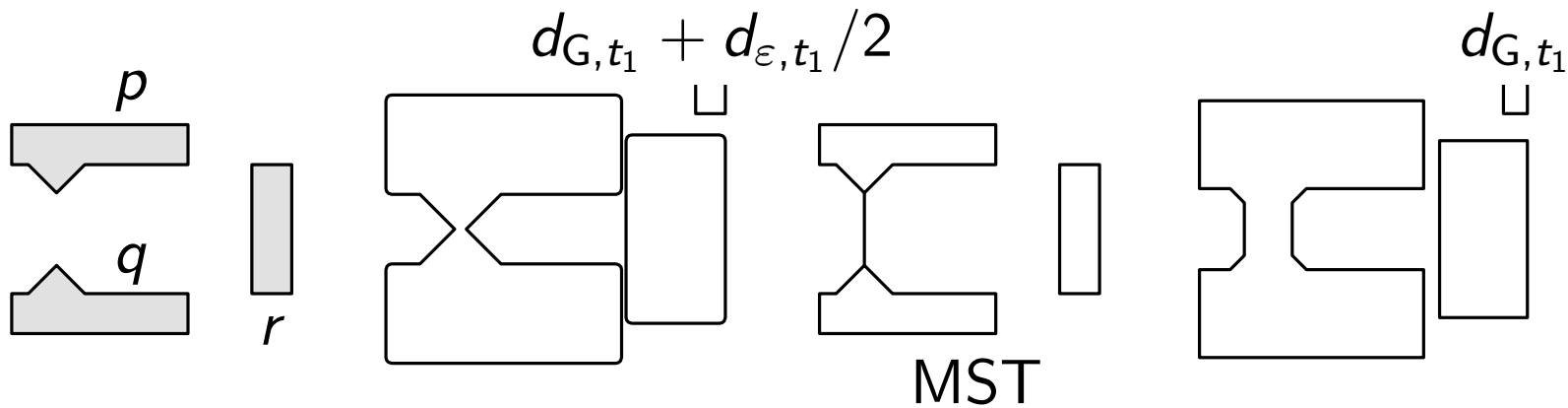
Merging Avoiding Shriking Bridges



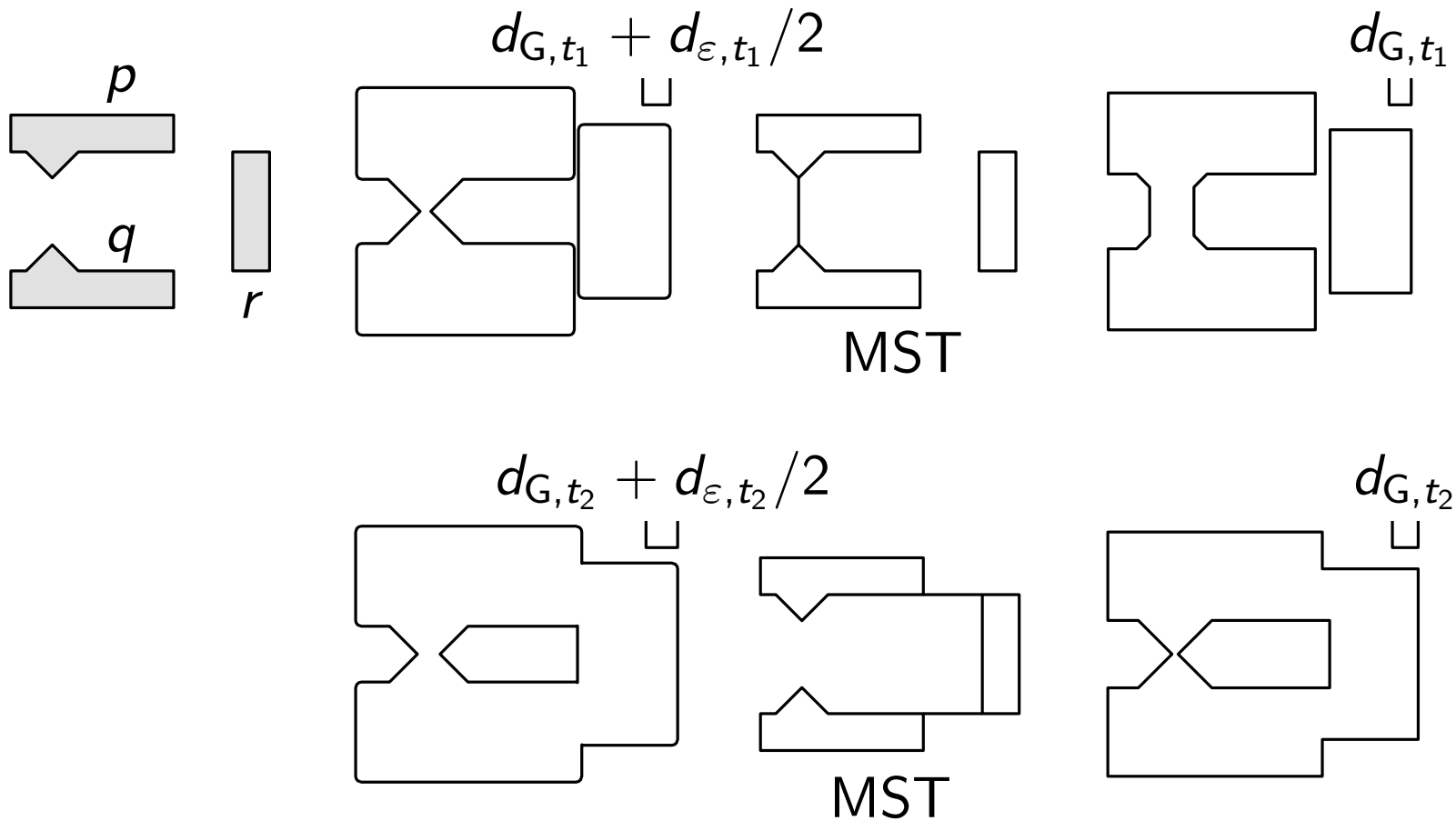
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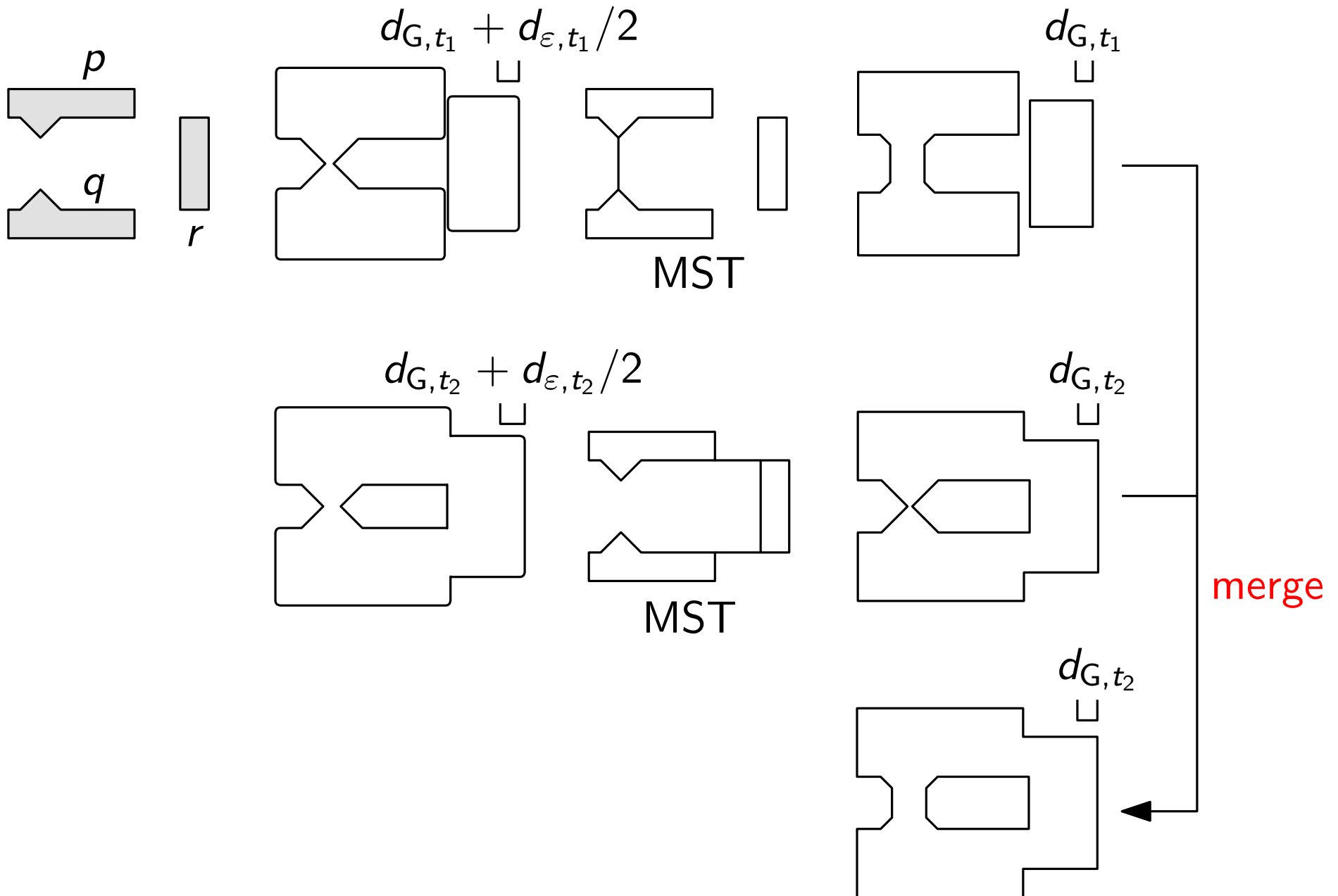
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Clipping by Goal Shape

Use the goal shape, at time $t = 1$, to clip the intermediate-scale results

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In this way, we avoid that intermediate-scale results may leave the goal shapes

Eliminating Small Buildings and Holes

- We eliminate a group building (or “building complex”) if its **total area** at time t is smaller than a_t .

$$a_t = a \cdot M_t^2, \text{ where } a = 0.16 \text{ mm}^2$$

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- We remove a hole if its area is less than $a_{h,t}$
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Outline

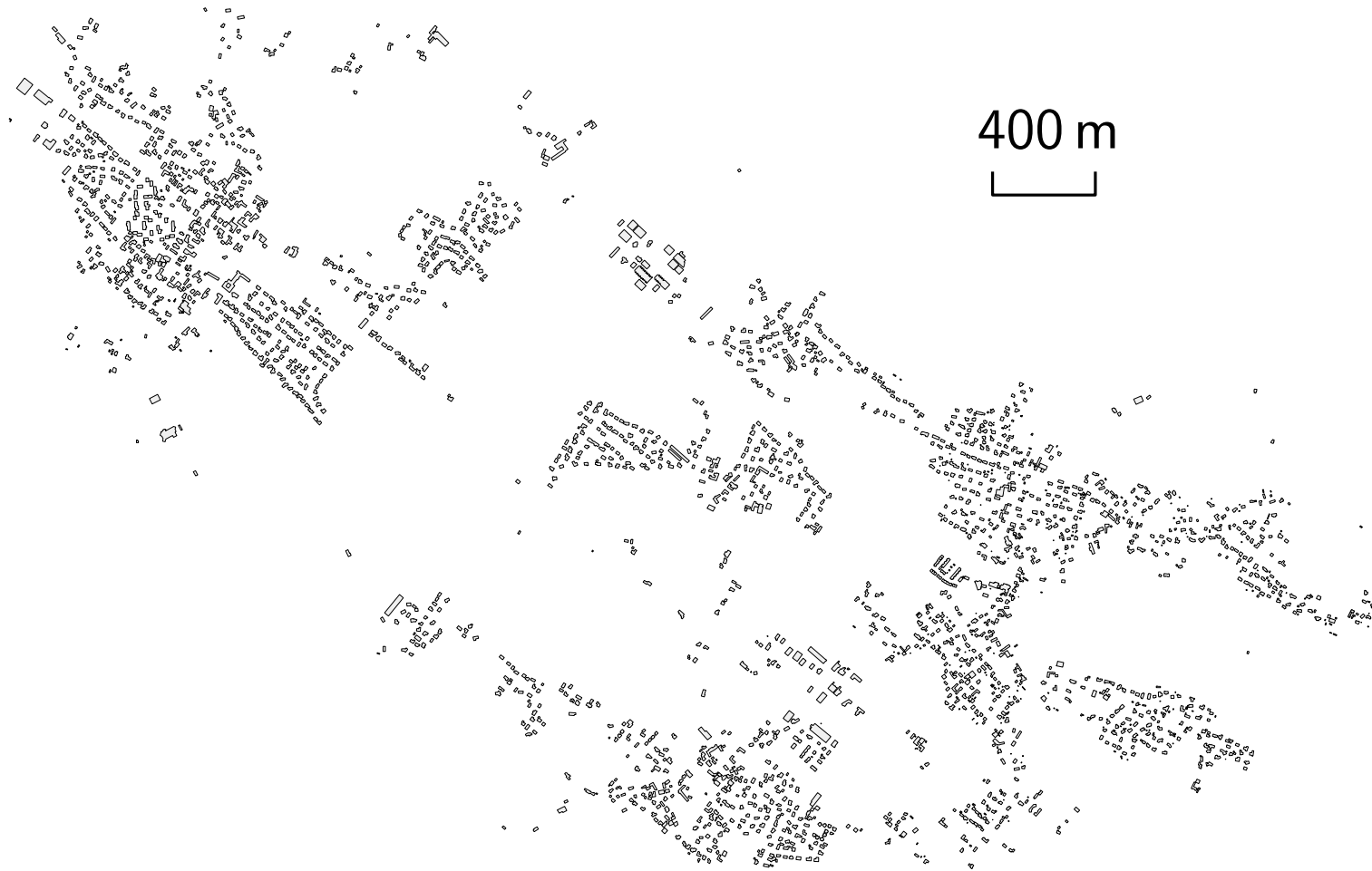
- Introduction
- Methodology
- Case Study
- Concluding Remarks

Case Study

Environment

- C# (using the .NET Framework 4.5)
- ArcObjects SDK 10.4.1
- Windows 7, 3.3 GHz dual core CPU, 8 GB RAM
- Time measure: Stopwatch (a class in C#)
- **CLIPPER**: buffering, dilation, erosion, and merge

Data



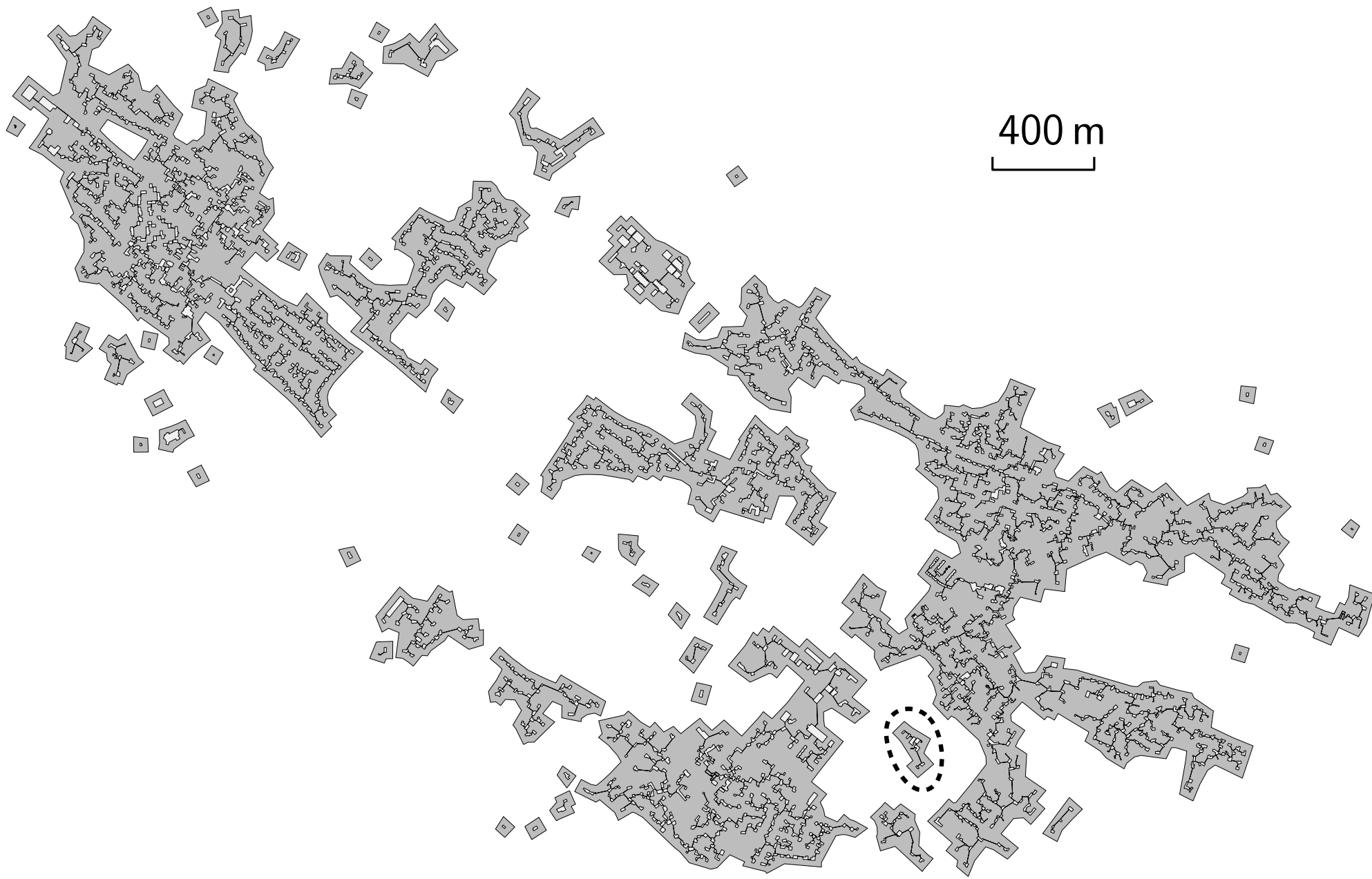
four towns in France, at scale 1 : 15,000, from IGN,
2,590 buildings, in total 19,255 edges,
we set $d_G = 25 \text{ m}$, and thus $d_{D,t} = t \cdot 35 \text{ m}$ and $d_{E,t} = t \cdot 7.5 \text{ m}$

Result

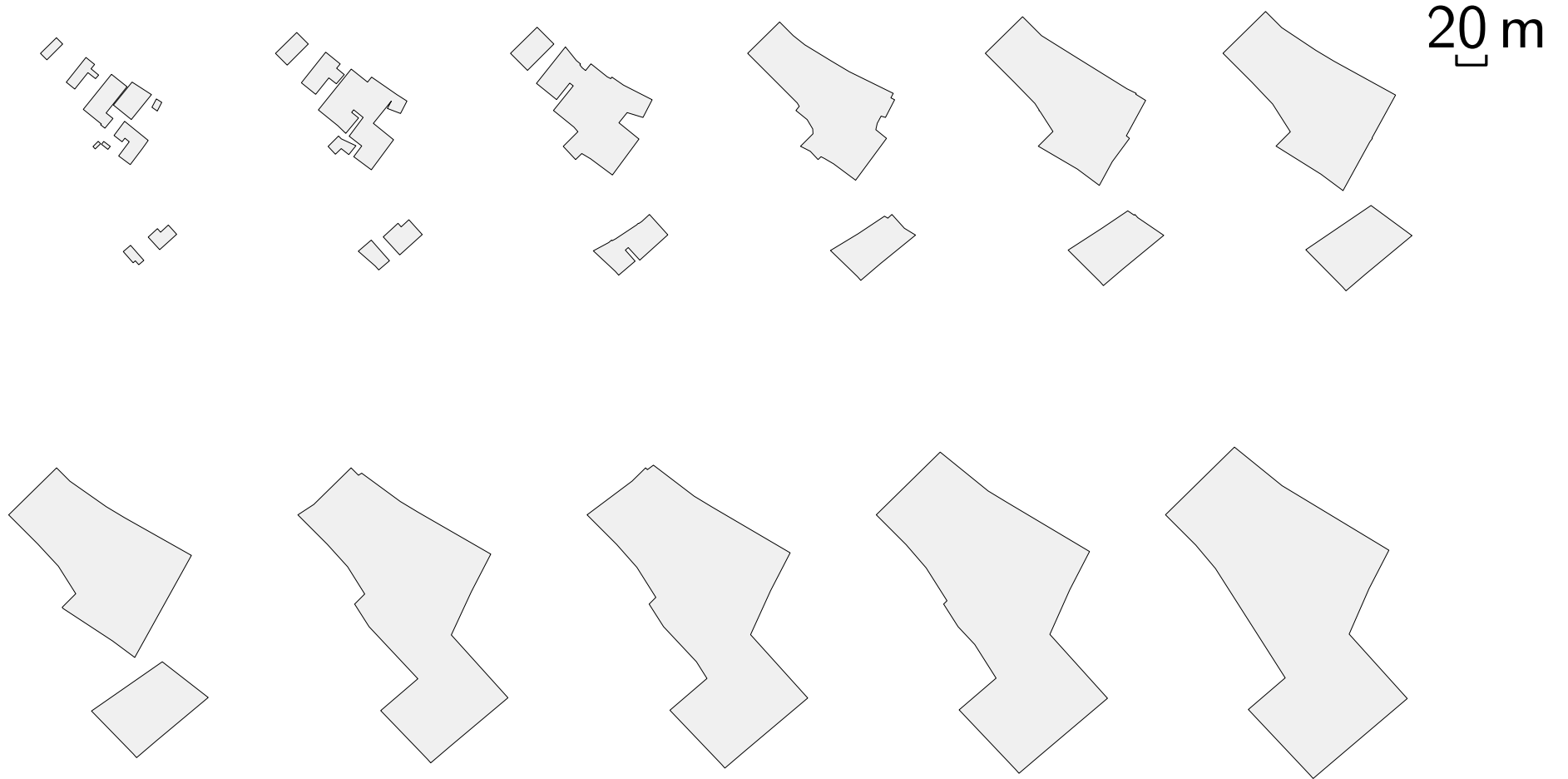
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- 668.2 s for computing a sequence of 10 maps



A sequence of maps



Outline

- Our Example Problem
- Methodology
- Case Study
- Concluding Remarks

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Advantages of our method:

- The buildings grow continuously and are simplified.
- Right angles of buildings are preserved during growing
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- Again, how much **total area** of buildings should be kept?
What about the total **number of edges**?
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Looking for a **postdoc** position!