Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Chair for
INFORMATICS I
Efficient Algorithms and
Knowledge-Based Systems

Institute for Informatics

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

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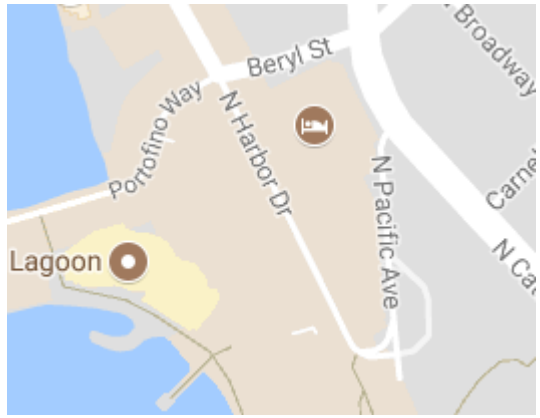
zoom out



(Google Maps)

Map Generalization. . .

. . . is about deriving a smaller-scale map from exsiting map.

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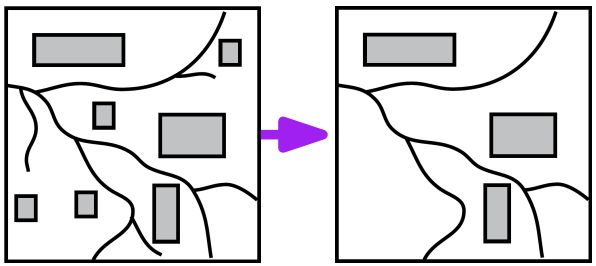
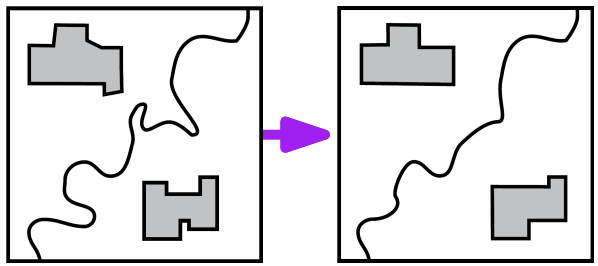
. . . is about deriving a smaller-scale map from exsiting map.

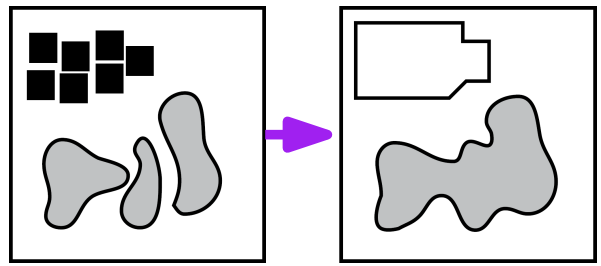
Typical generalization operators (ESRI 1996):



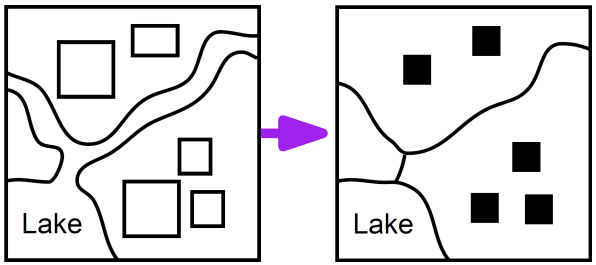
Elimination



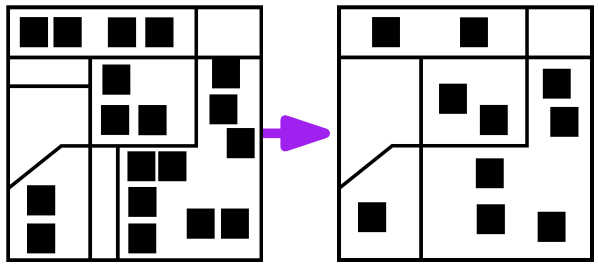
Simplification



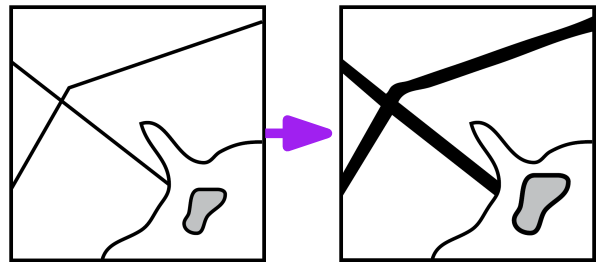
Aggregation



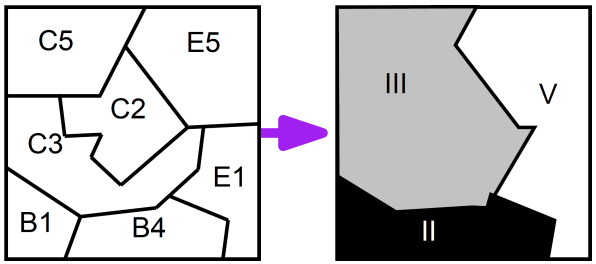
Collapse



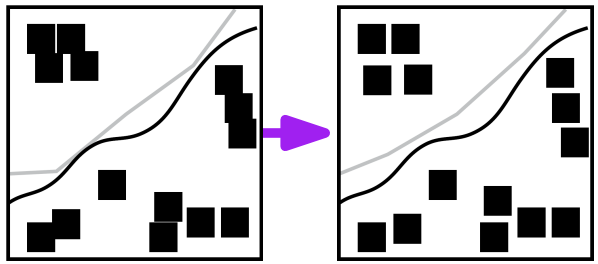
Typification



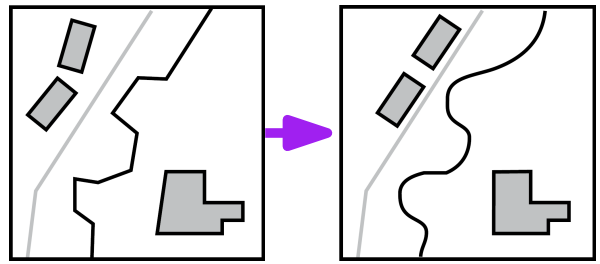
Exaggeration



Classifi. and symboli.



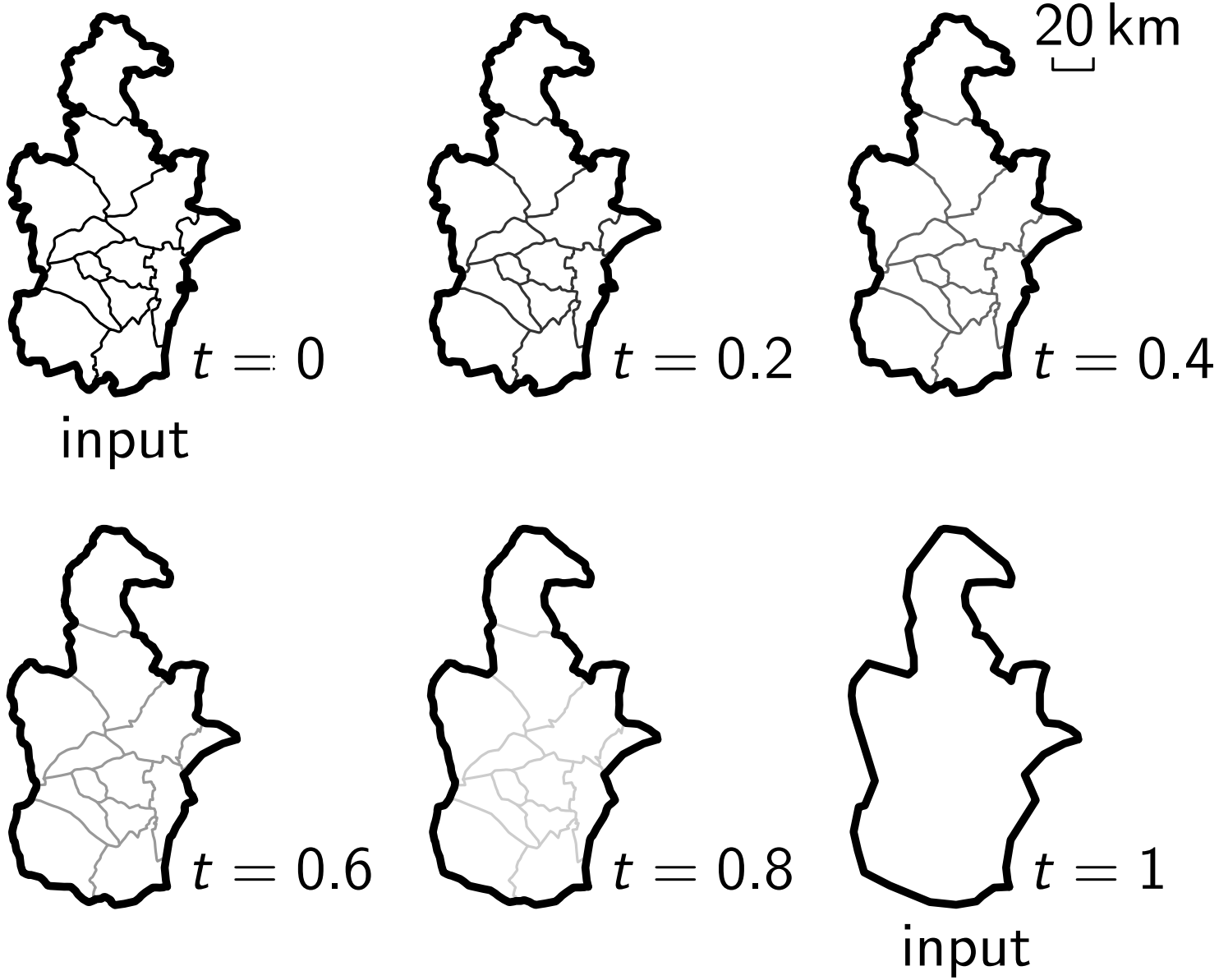
Displacement



Refinement

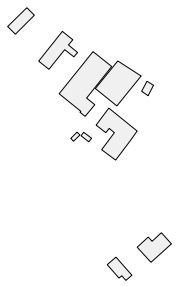
Continuous Map Generalization...

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



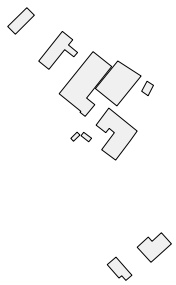
Research Problem

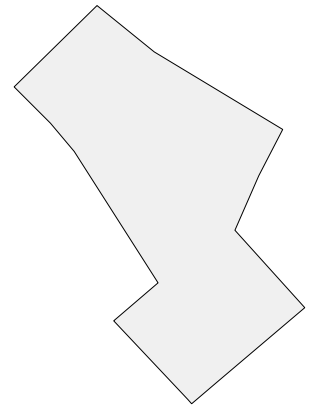
input



Research Problem

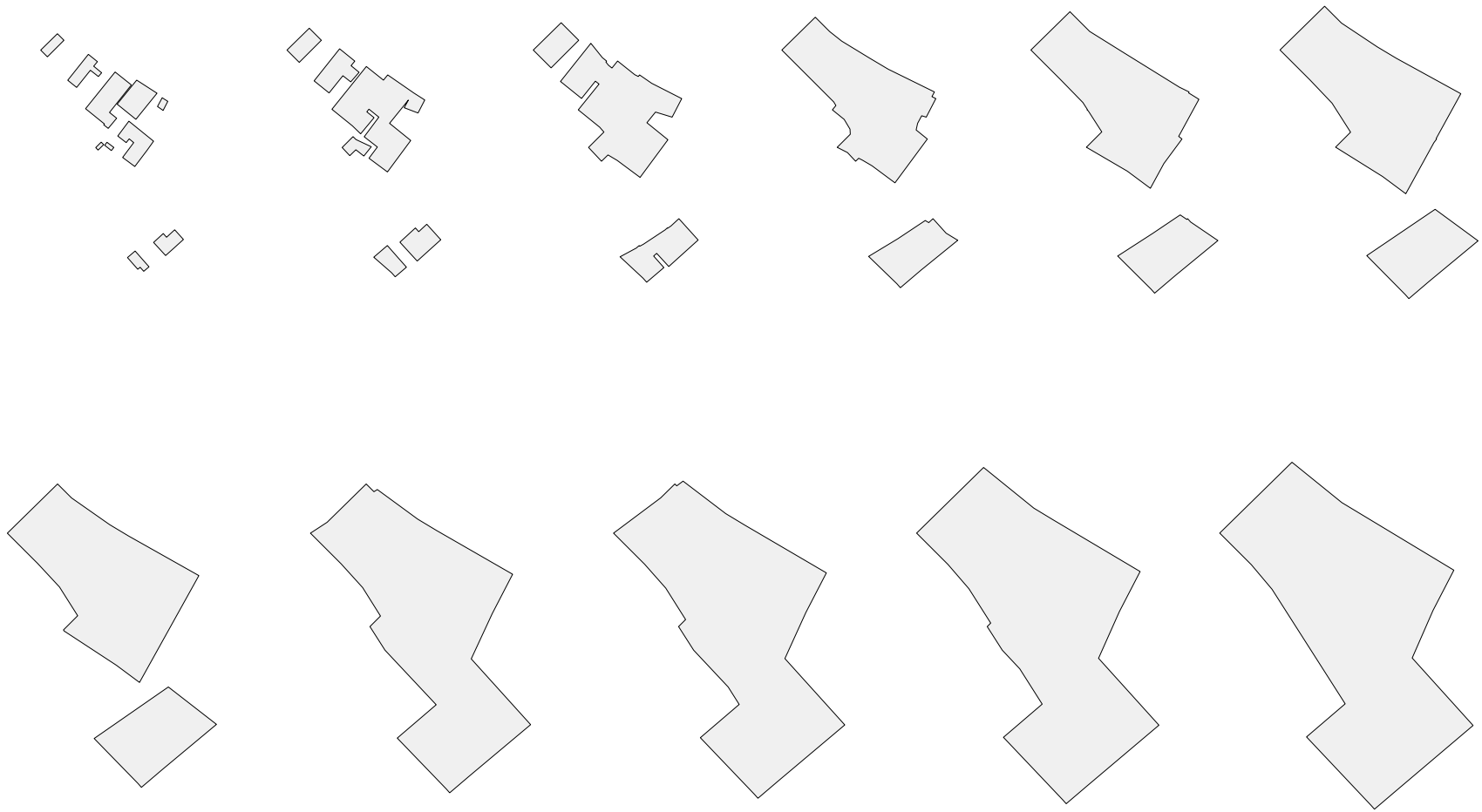
input





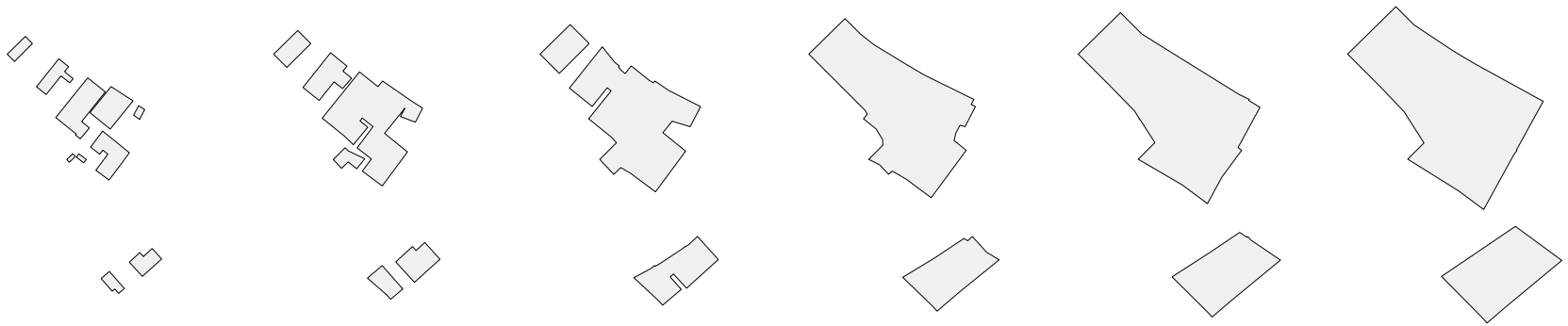
Research Problem

input

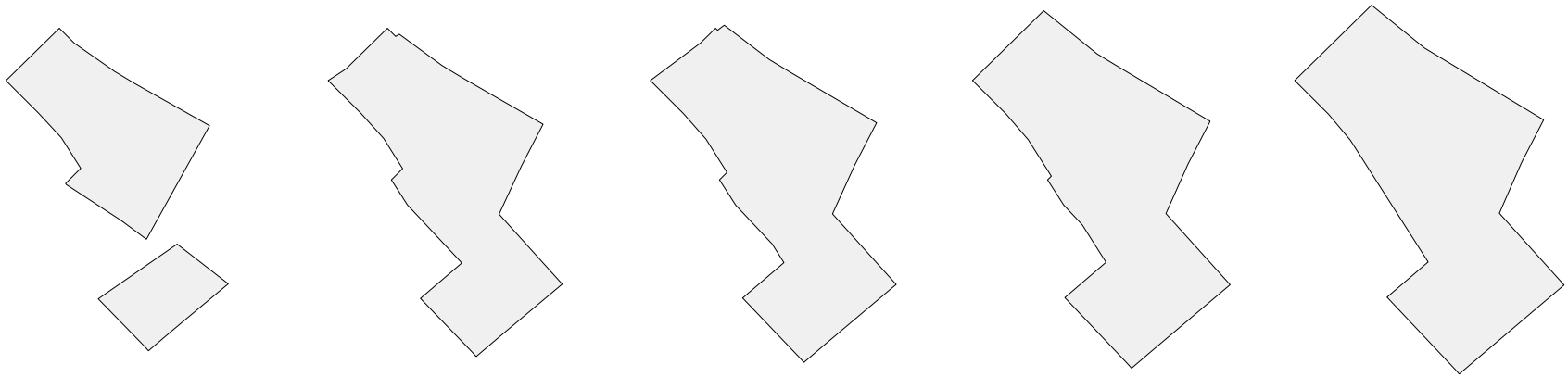


Research Problem

input

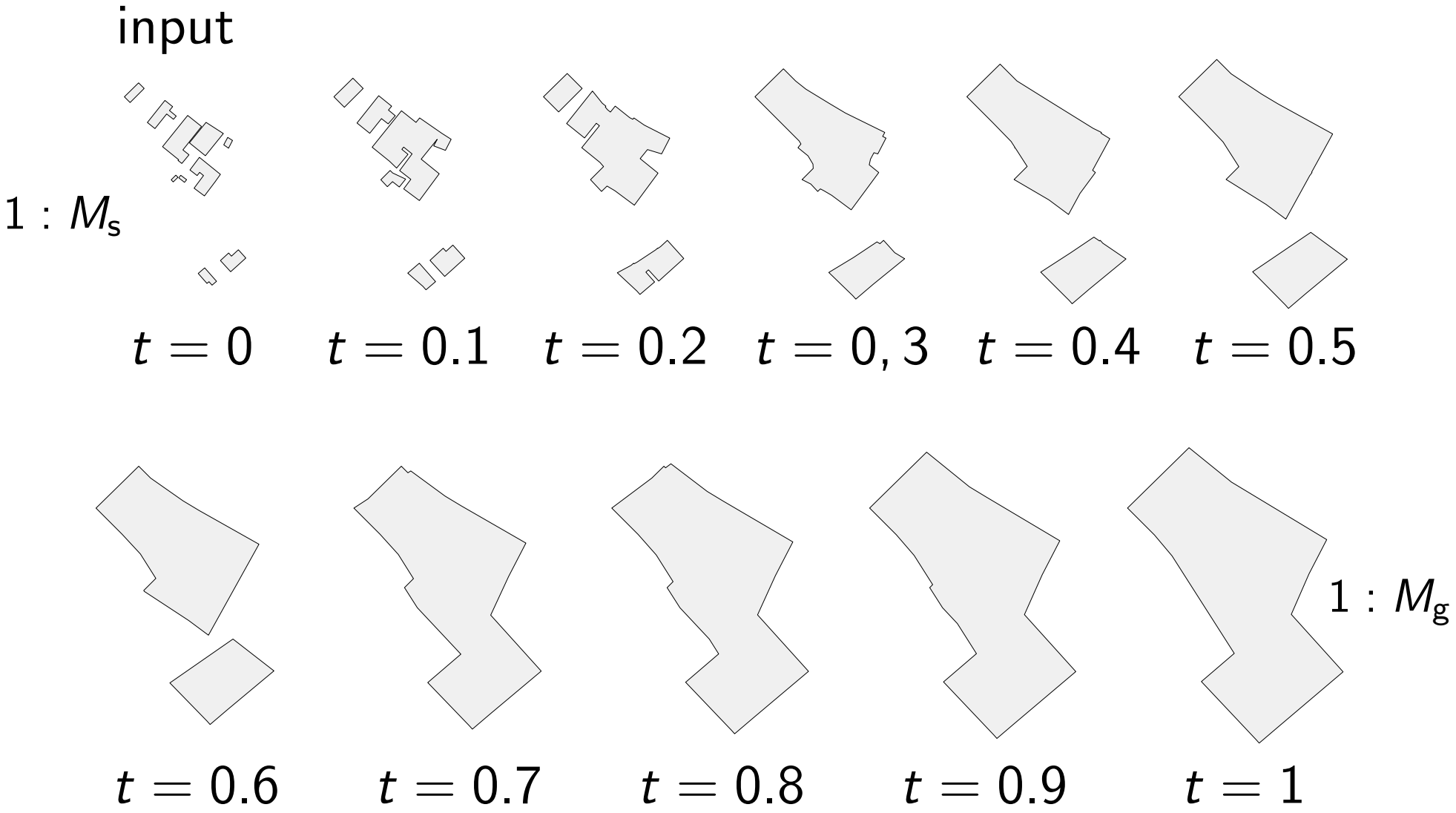


$t = 0$ $t = 0.1$ $t = 0.2$ $t = 0,3$ $t = 0.4$ $t = 0.5$



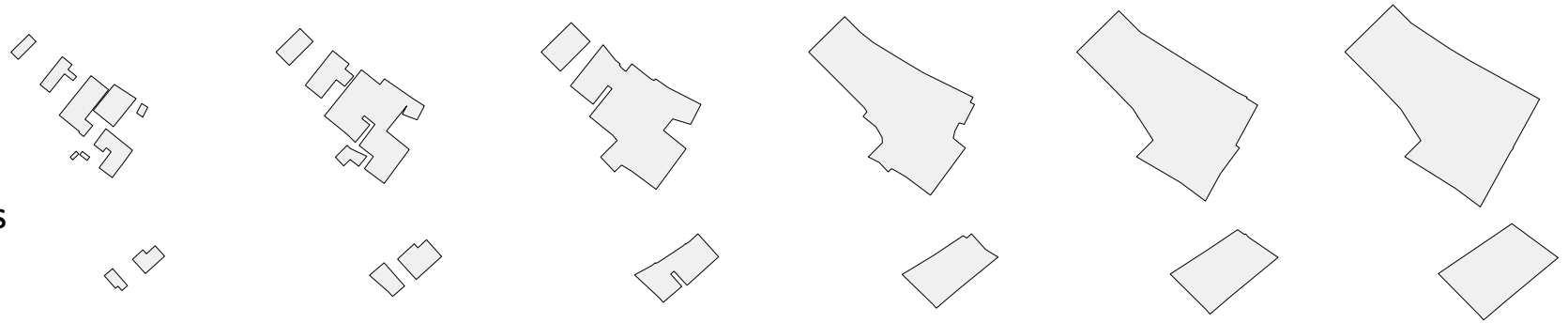
$t = 0.6$ $t = 0.7$ $t = 0.8$ $t = 0.9$ $t = 1$

Research Problem



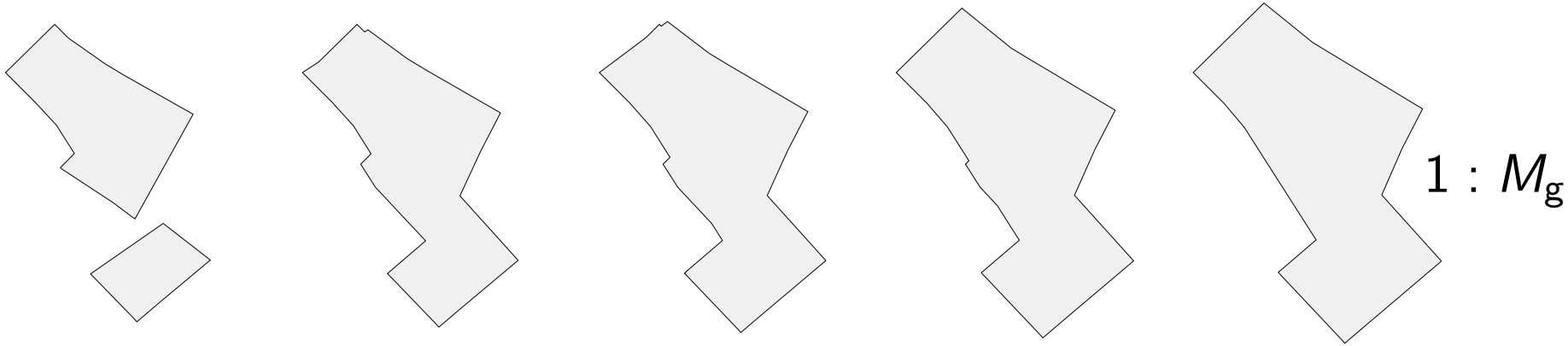
Research Problem

input



$1 : M_s$

$t = 0$ $t = 0.1$ $t = 0.2$ $t = 0,3$ $t = 0.4$ $t = 0.5$



$1 : M_g$

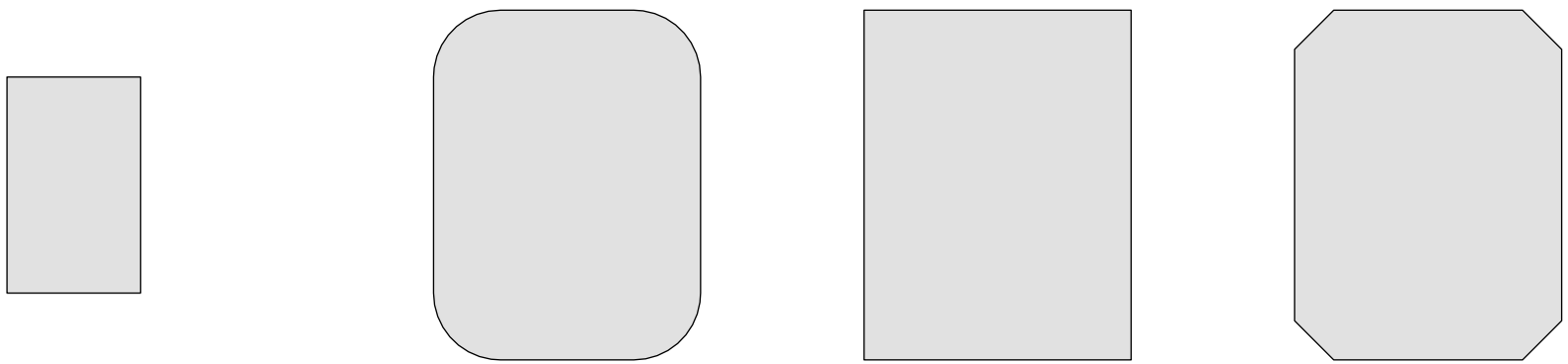
$t = 0.6$ $t = 0.7$ $t = 0.8$ $t = 0.9$ $t = 1$

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

Outline

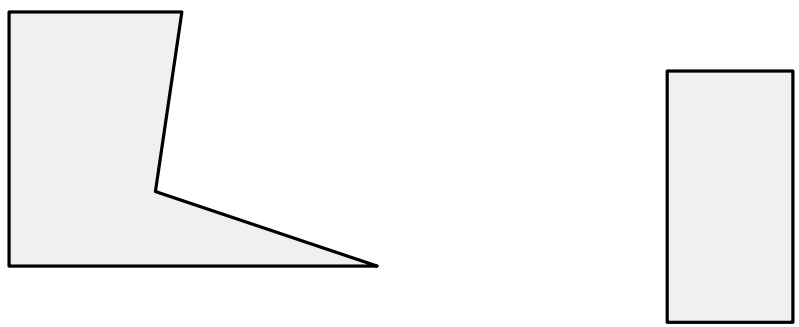
- Introduction
- Methodology
- Case Study
- Concluding Remarks

Three Types of Buffering

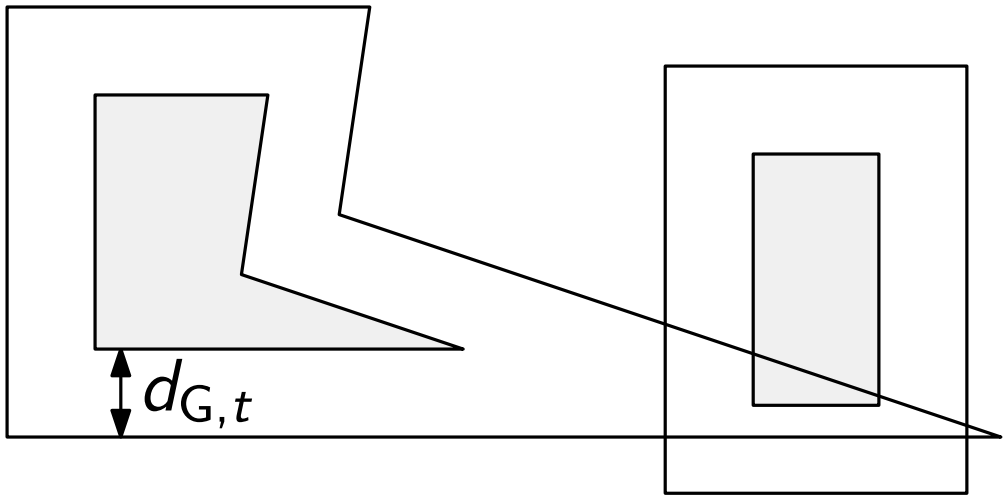


rectangle round miter square

Growing Buildings by Buffering

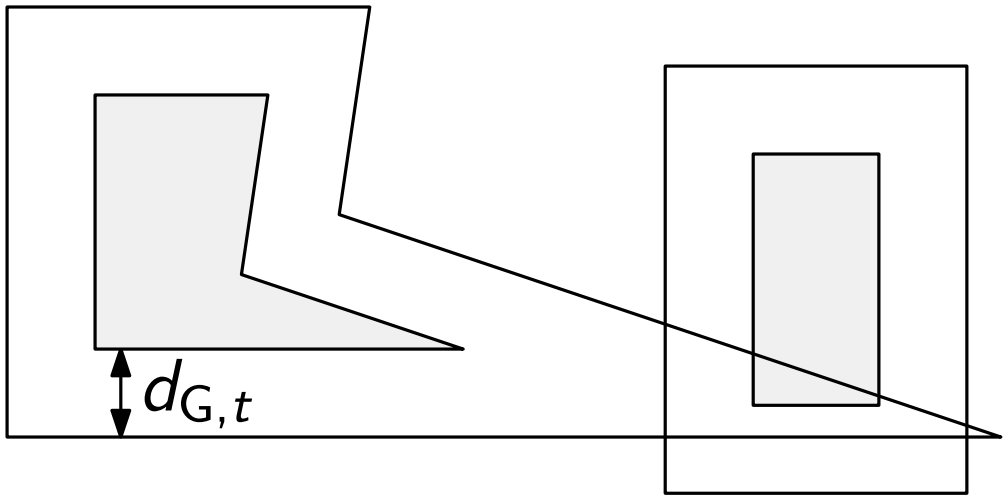


Growing Buildings by Buffering



buffering using miter joins to keep right angles

Growing Buildings by Buffering

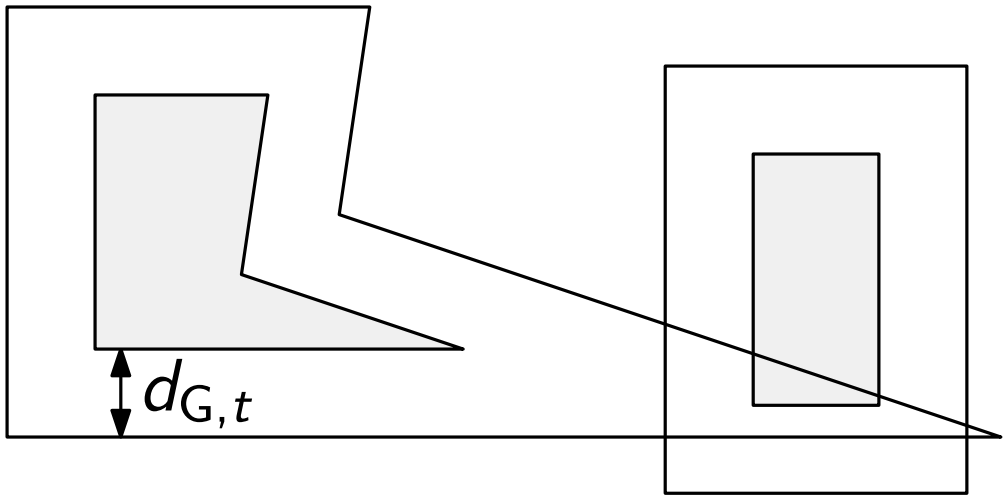


$d_{G,t} = t \cdot d_G$

d_G: input

buffering using miter joins to keep right angles

Growing Buildings by Buffering



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

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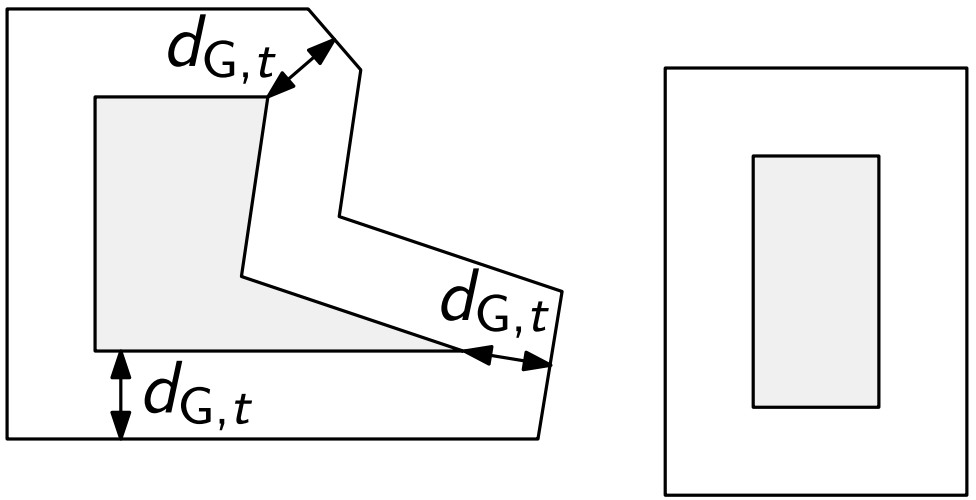
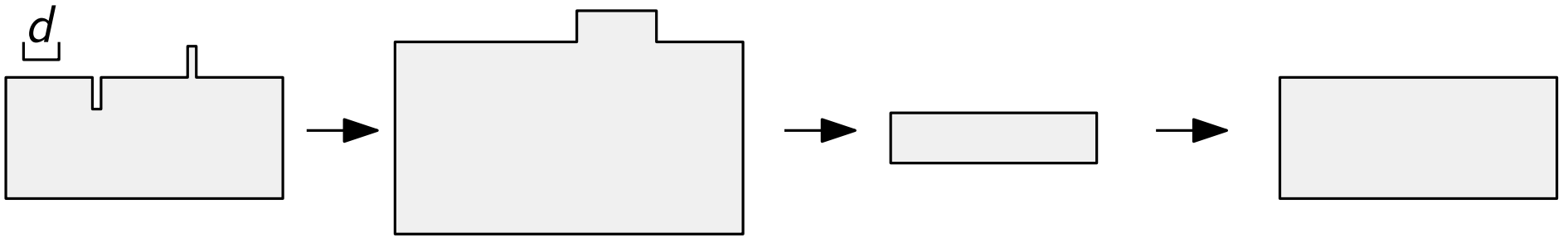
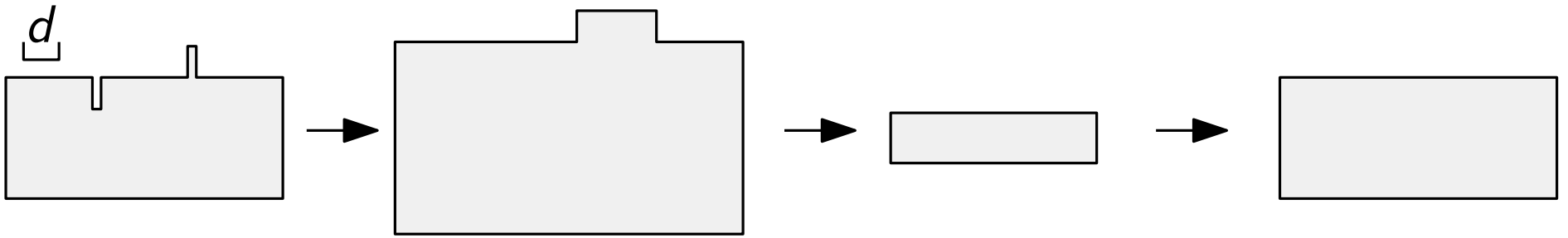


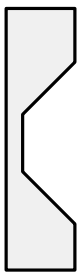
squaring if spikes are too long:
distance larger than $\alpha d_{G,t}$, where we set $\alpha = 1.5$

Simpifying Based on Dilation and Erosion



Simpifying Based on Dilation and Erosion





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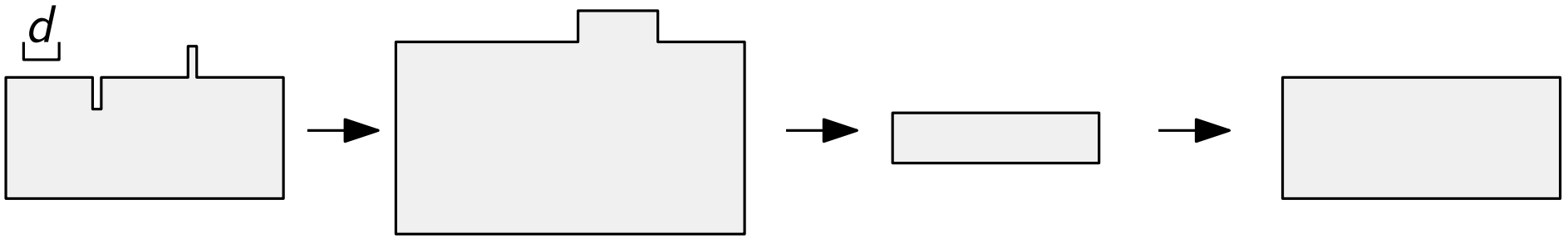
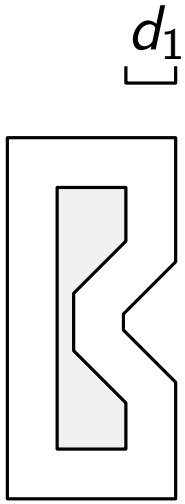
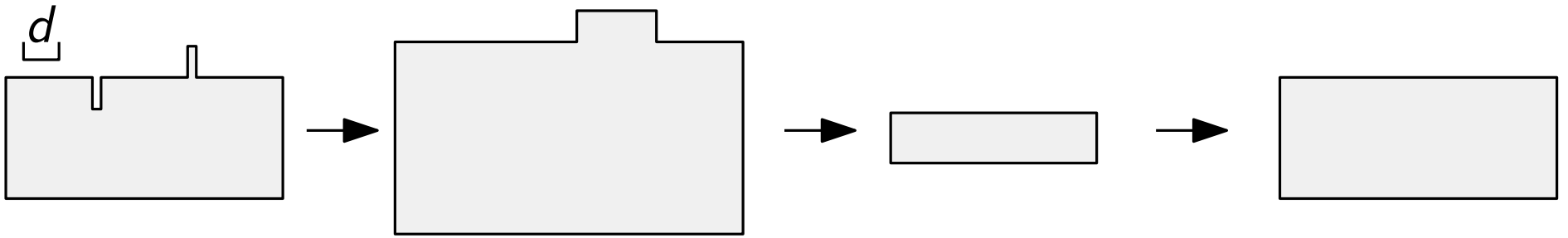
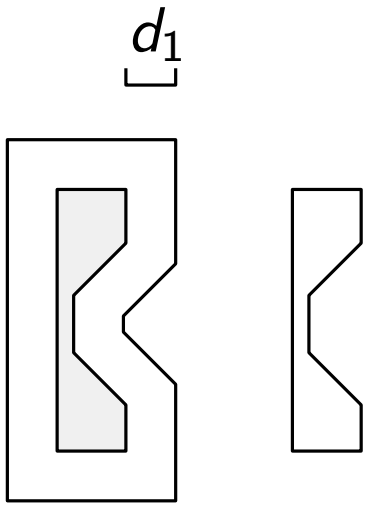




Simpifying Based on Dilation and Erosion





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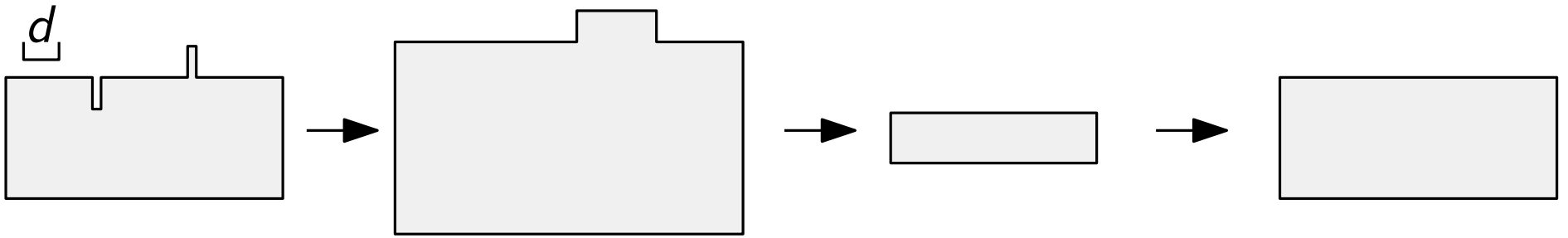

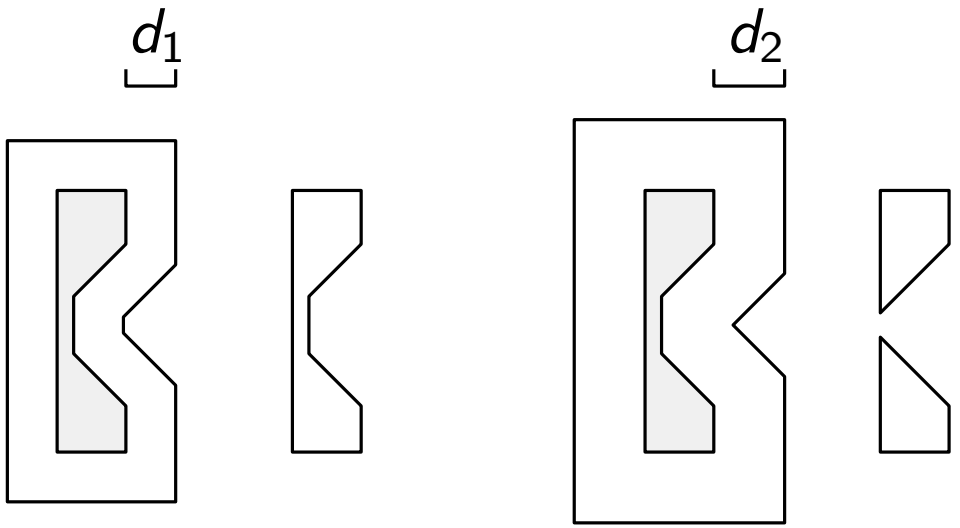

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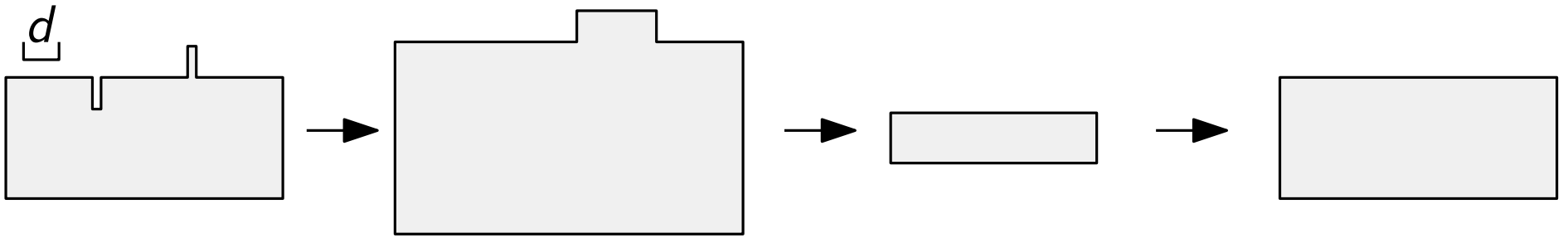
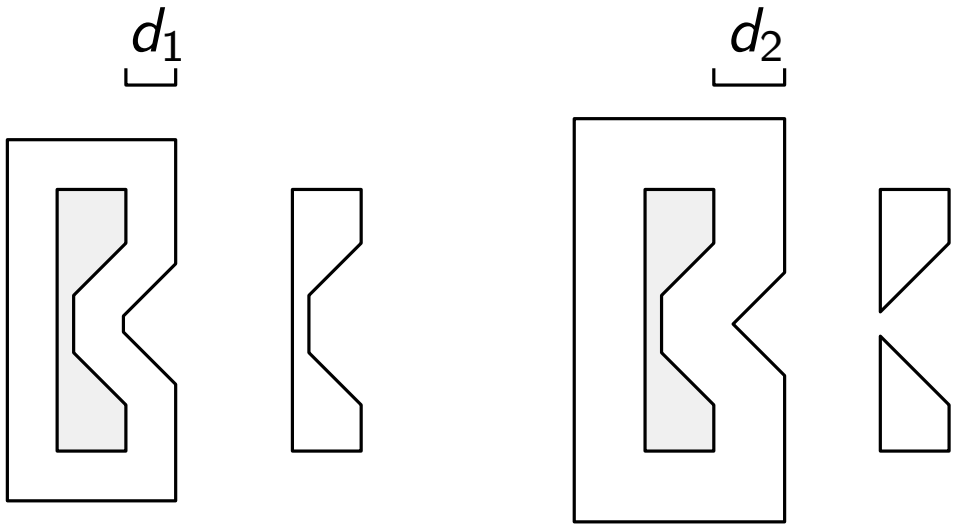
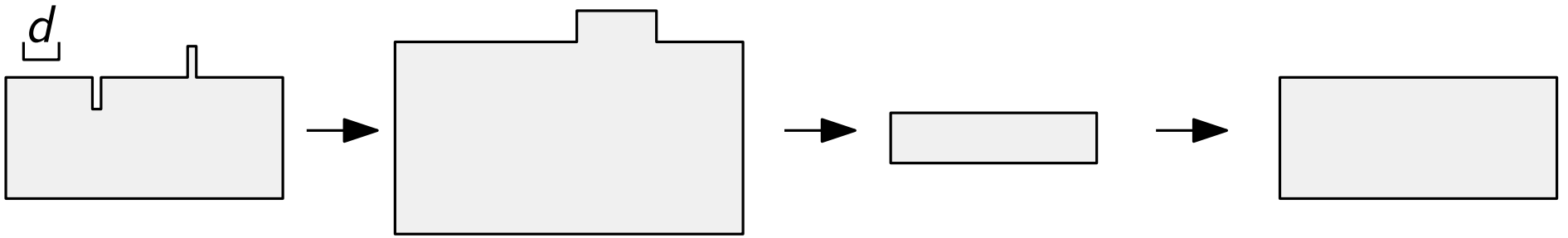
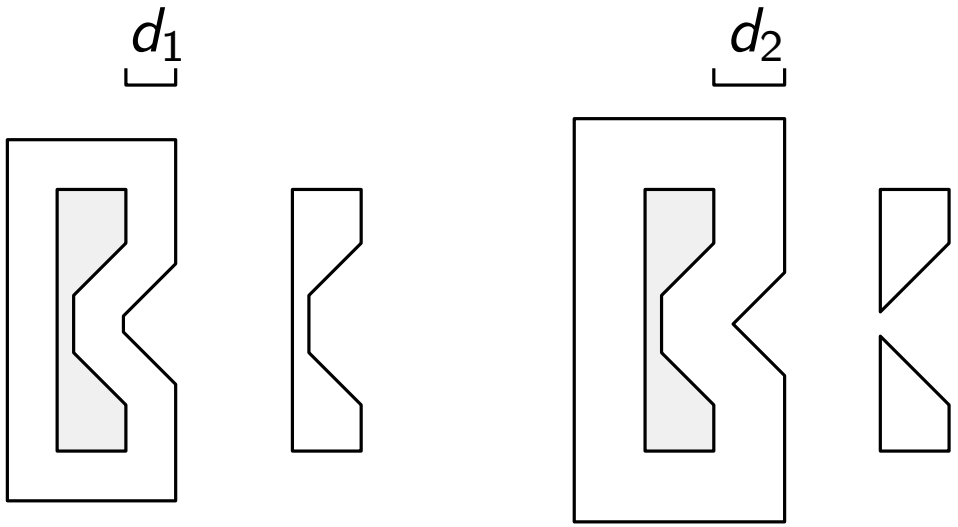




$$d_{\mathrm{E},t} = t \cdot \tfrac{\ell}{2} M_{\mathrm{g}}$$
$$\ell = 0.3\,\mathrm{mm}$$

Simpifying Based on Dilation and Erosion





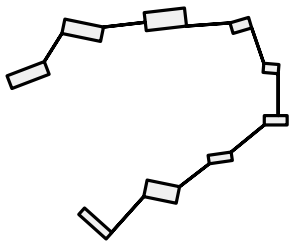
$$d_{\mathrm{E},t} = t \cdot \tfrac{\ell}{2} M_{\mathrm{g}}$$

$$\ell = 0.3\,\mathrm{mm}$$

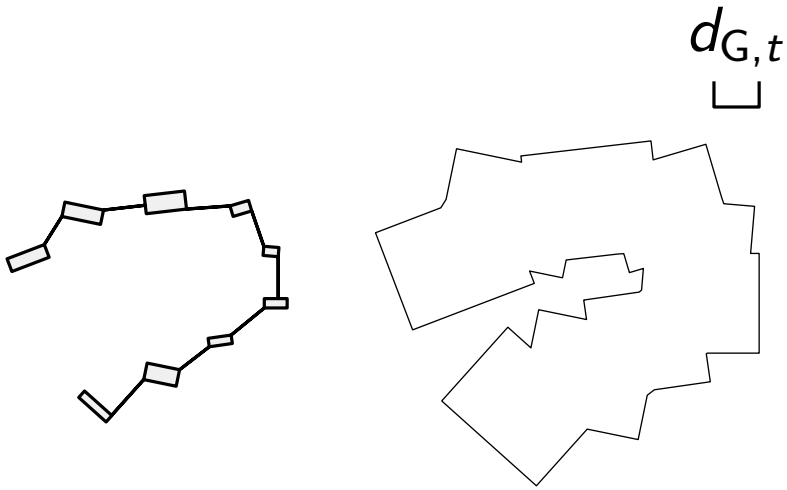
avoid breaking:

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

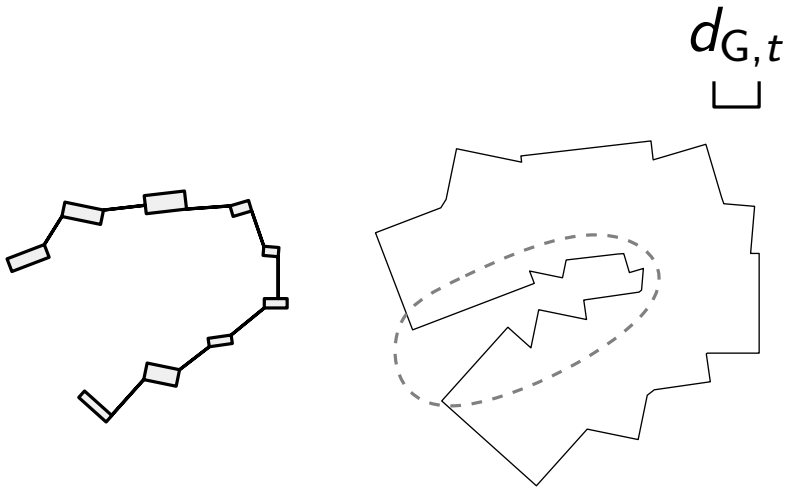
A “bay” Removed by Dilation



A “bay” Removed by Dilation



A “bay” Removed by Dilation



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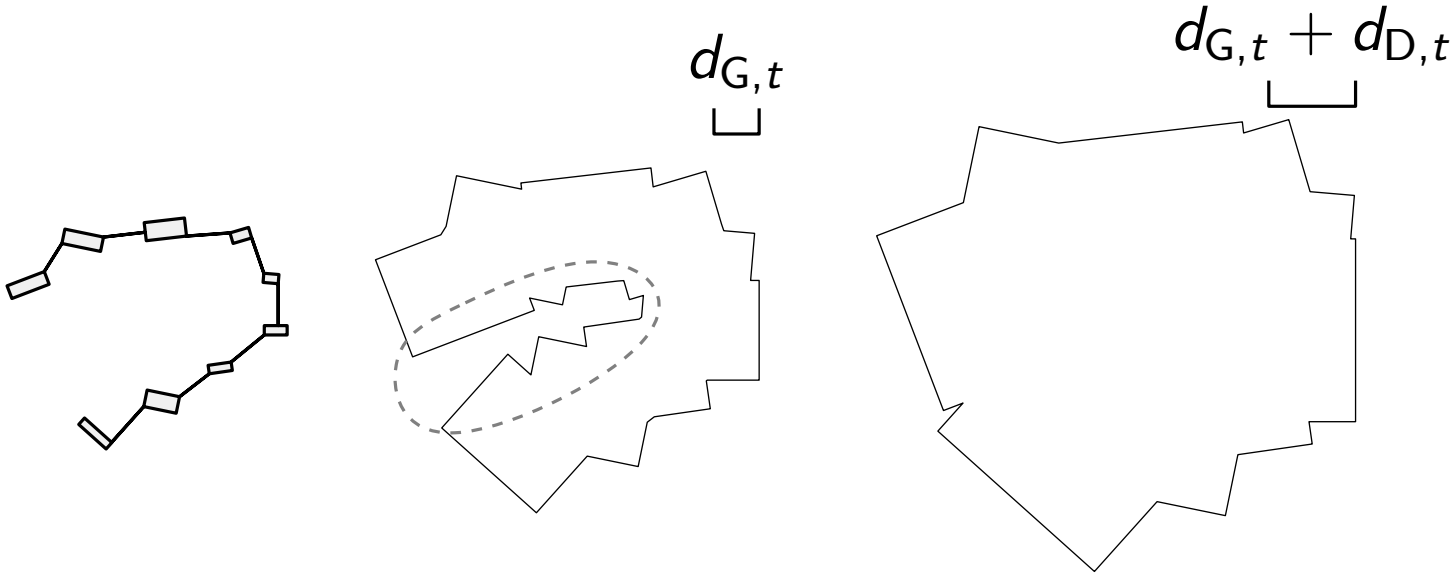
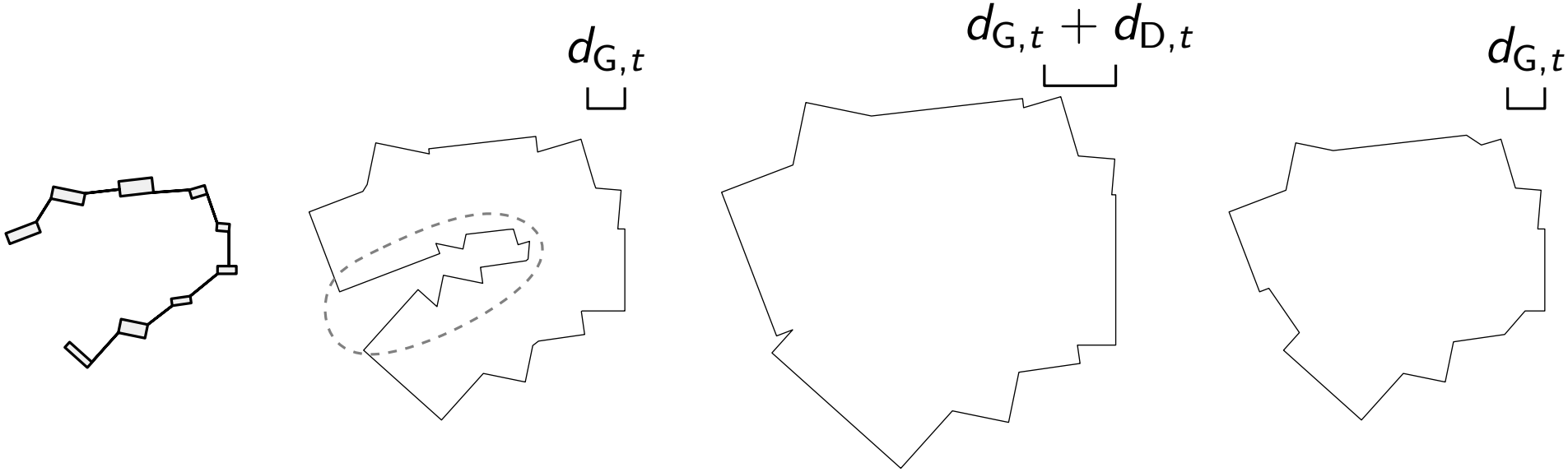
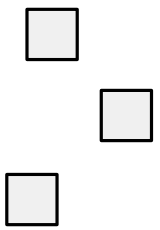


A “bay” Removed by Dilation



Aggregating Buildings by Adding Bridges

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



original buildings

$t = 0$

Aggregating Buildings by Adding Bridges

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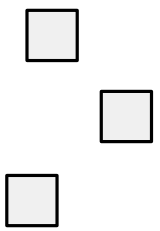
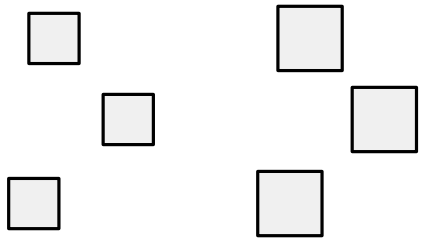
  a minimum spanning tree (MST)



original buildings

$t = 0$

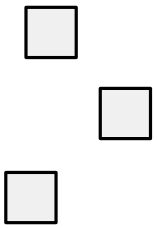


bridge grow

$t = 0.4$

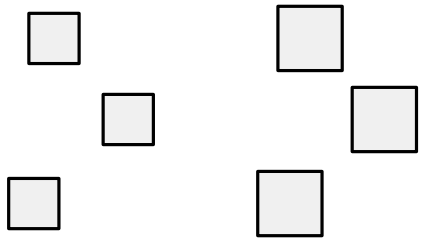
Aggregating Buildings by Adding Bridges

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



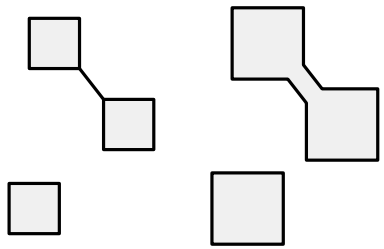
original buildings

$t = 0$



bridge grow

$t = 0.4$

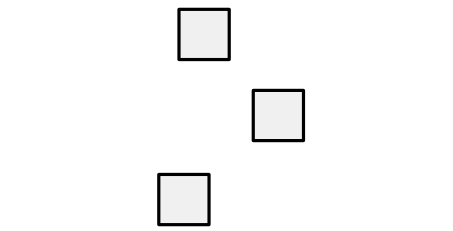


bridge grow

$t = 0.6$

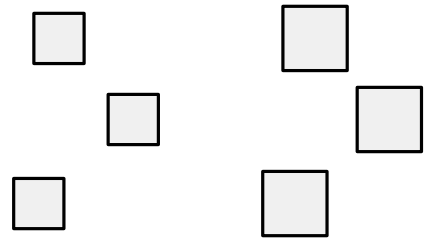
Aggregating Buildings by Adding Bridges

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



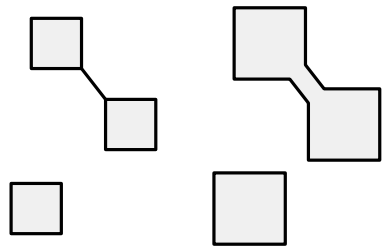
original buildings

$t = 0$



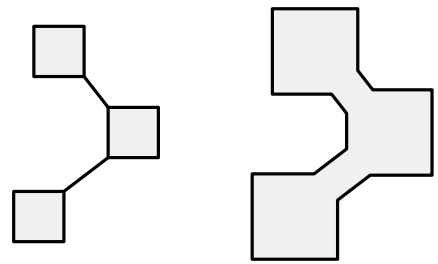
bridge grow

$t = 0.4$



bridge grow

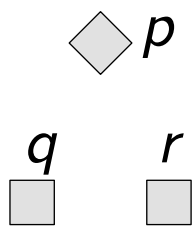
$t = 0.6$



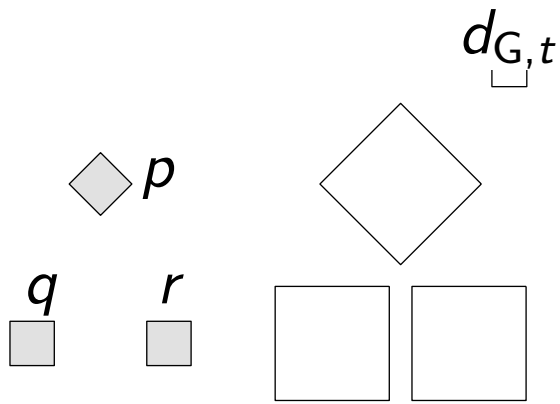
bridge grow

$t = 1$

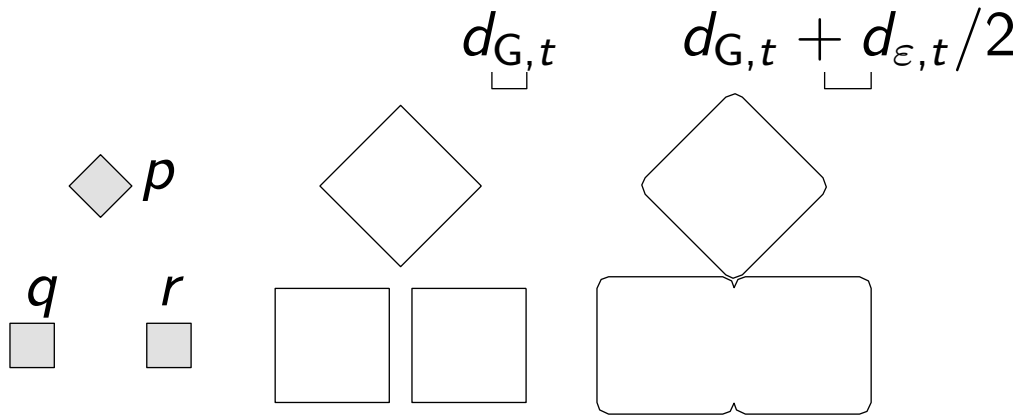
Iteratively Aggregating



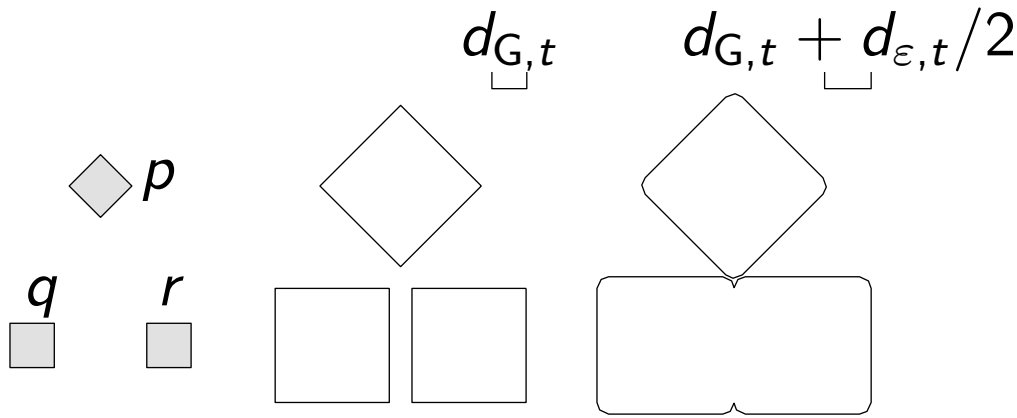
Iteratively Aggregating



Iteratively Aggregating



Iteratively Aggregating



two buildings are too close:
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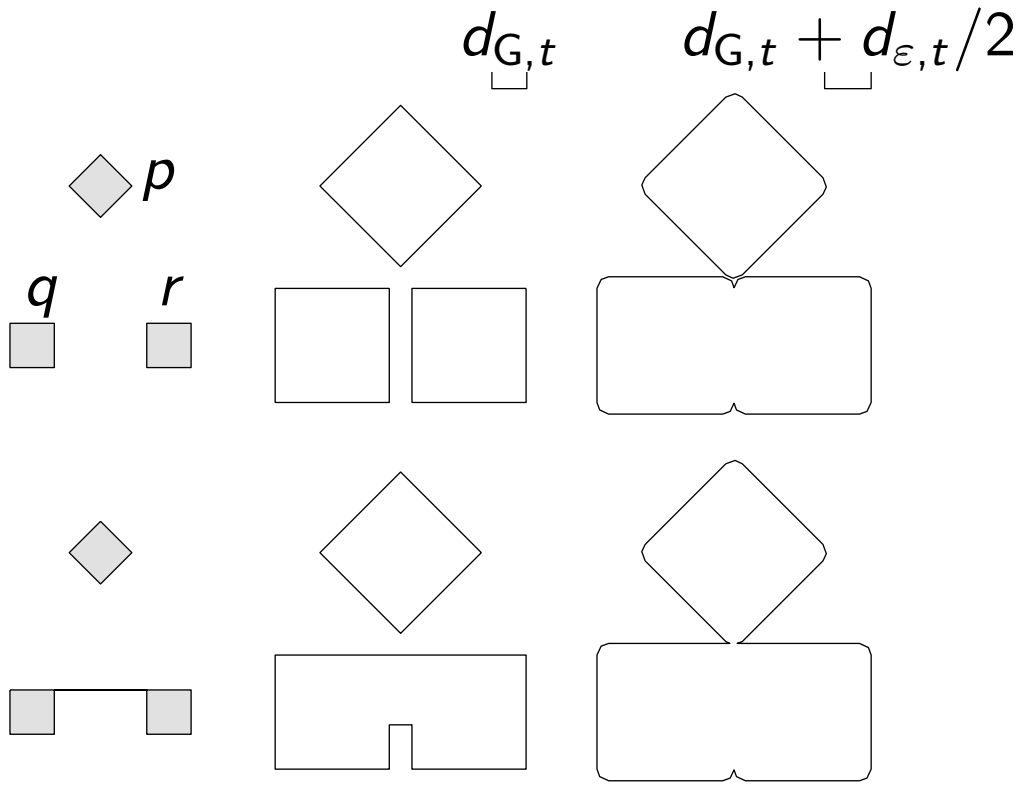

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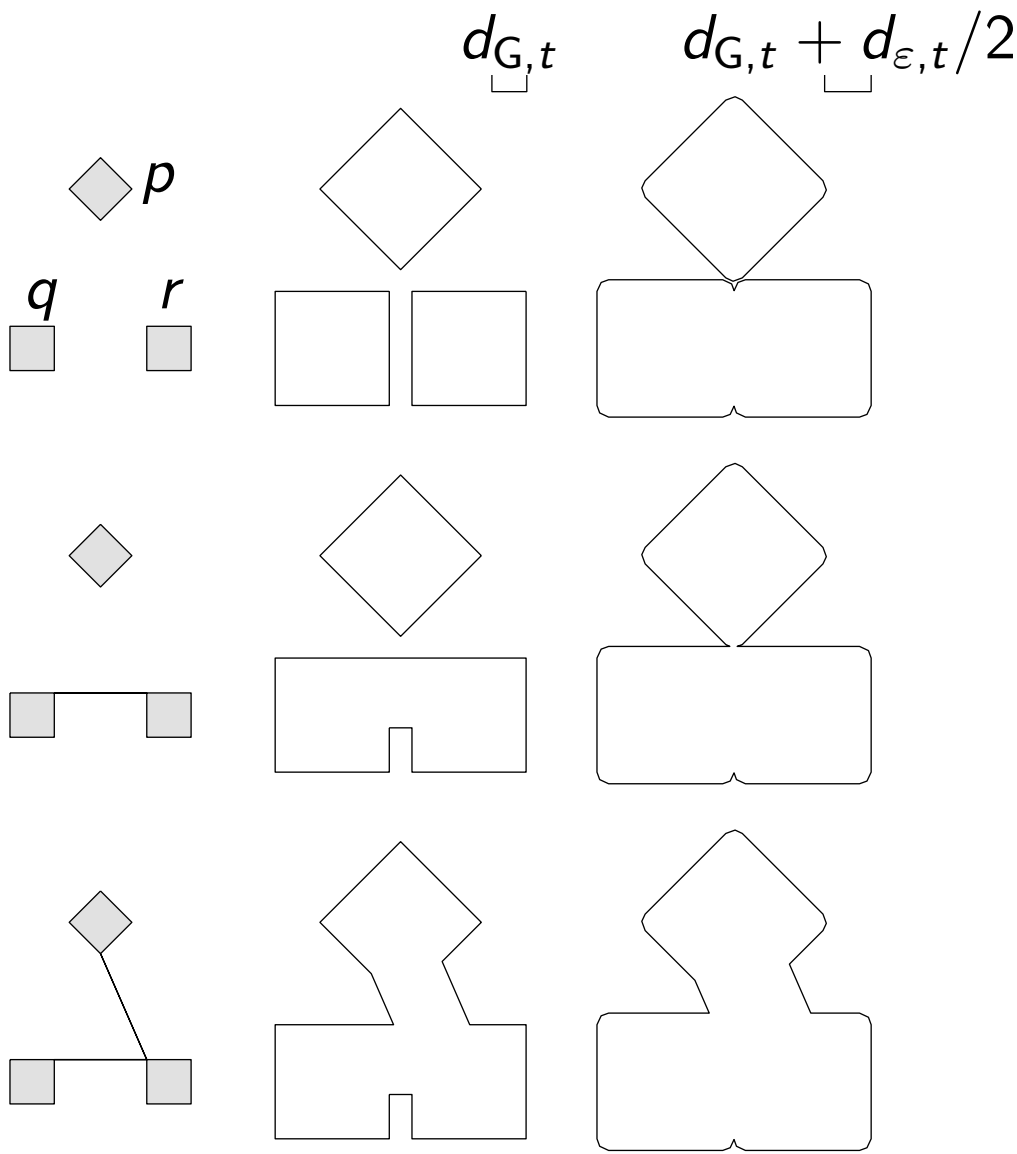

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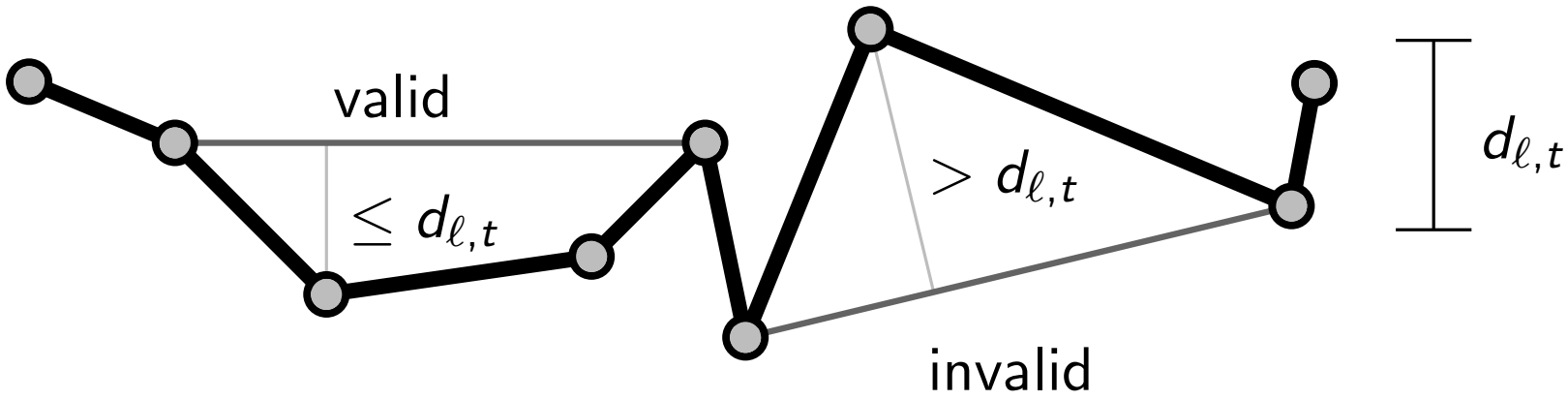
Simplifying Using Imai–Iri Algorithm

- Finding all valid shortcuts

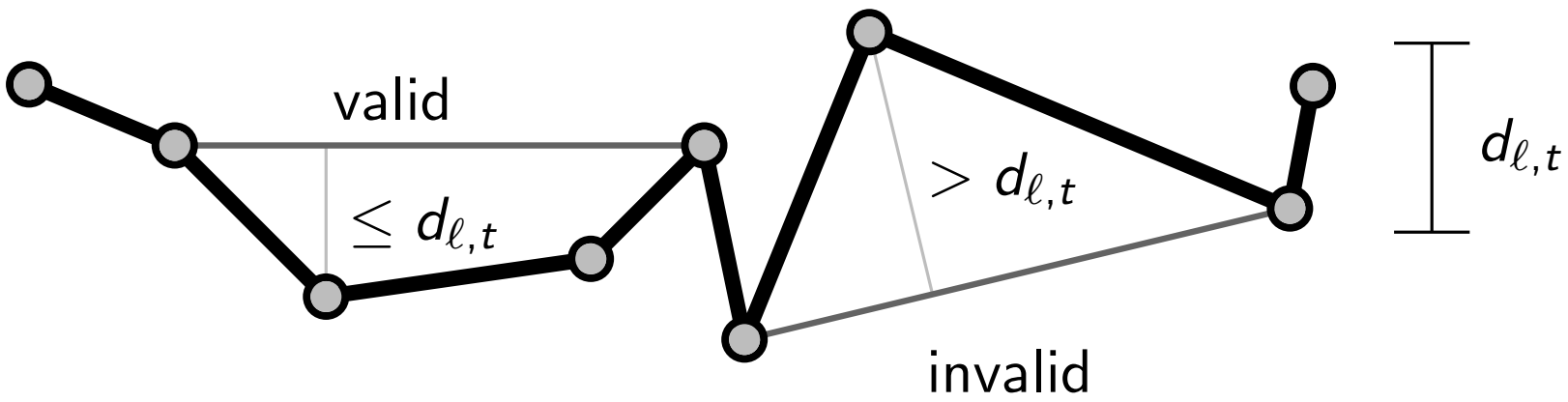


$d_{\ell,t} = \ell \cdot M_t$

$\ell = 0.3\,\mathrm{mm}$

Simplifying Using Imai–Iri Algorithm

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



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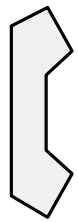
Producing Intermediate-scale maps

A building may shrink because of erosion



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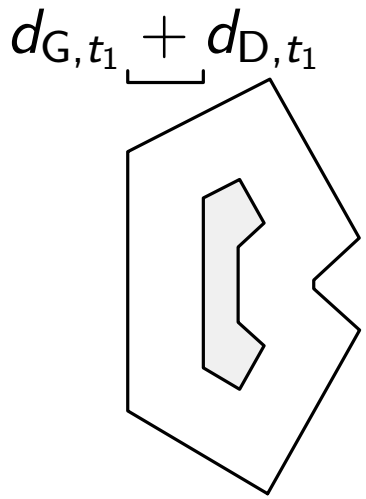

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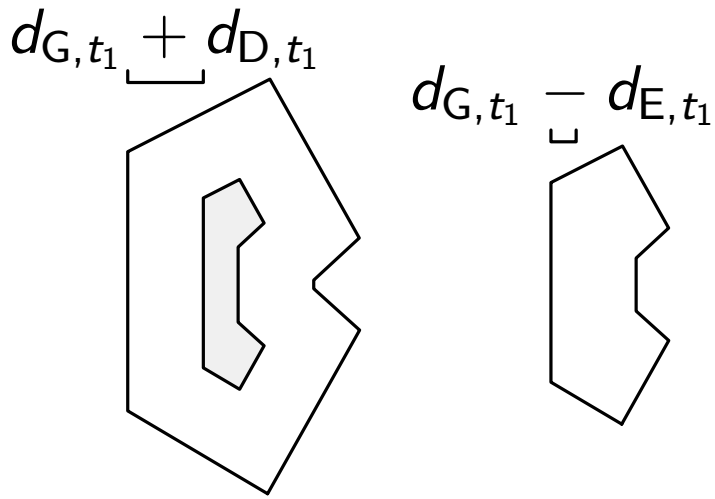

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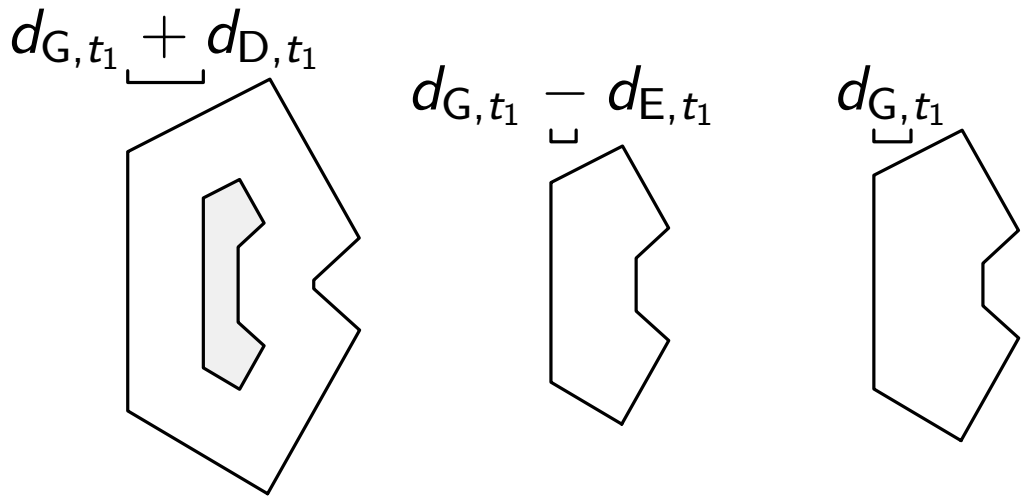

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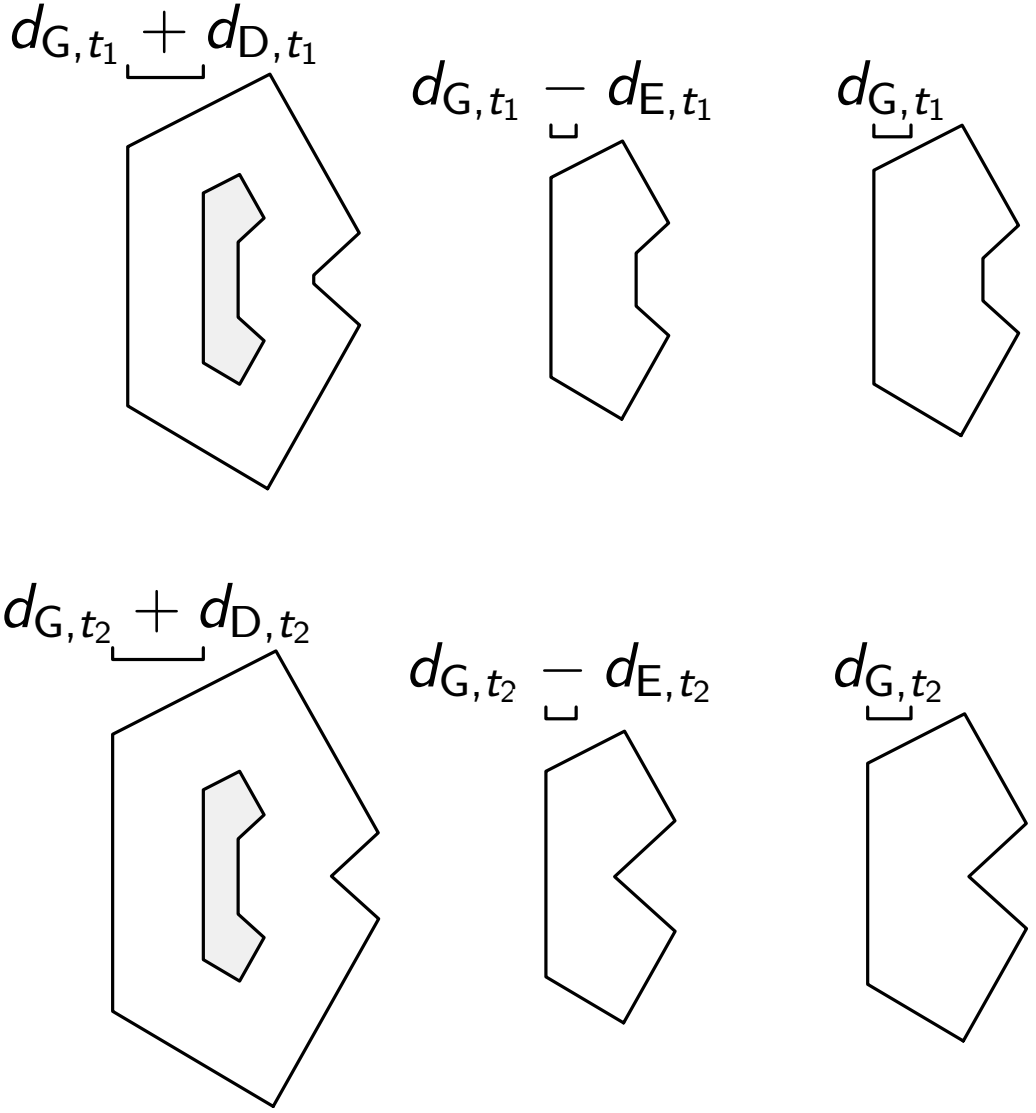

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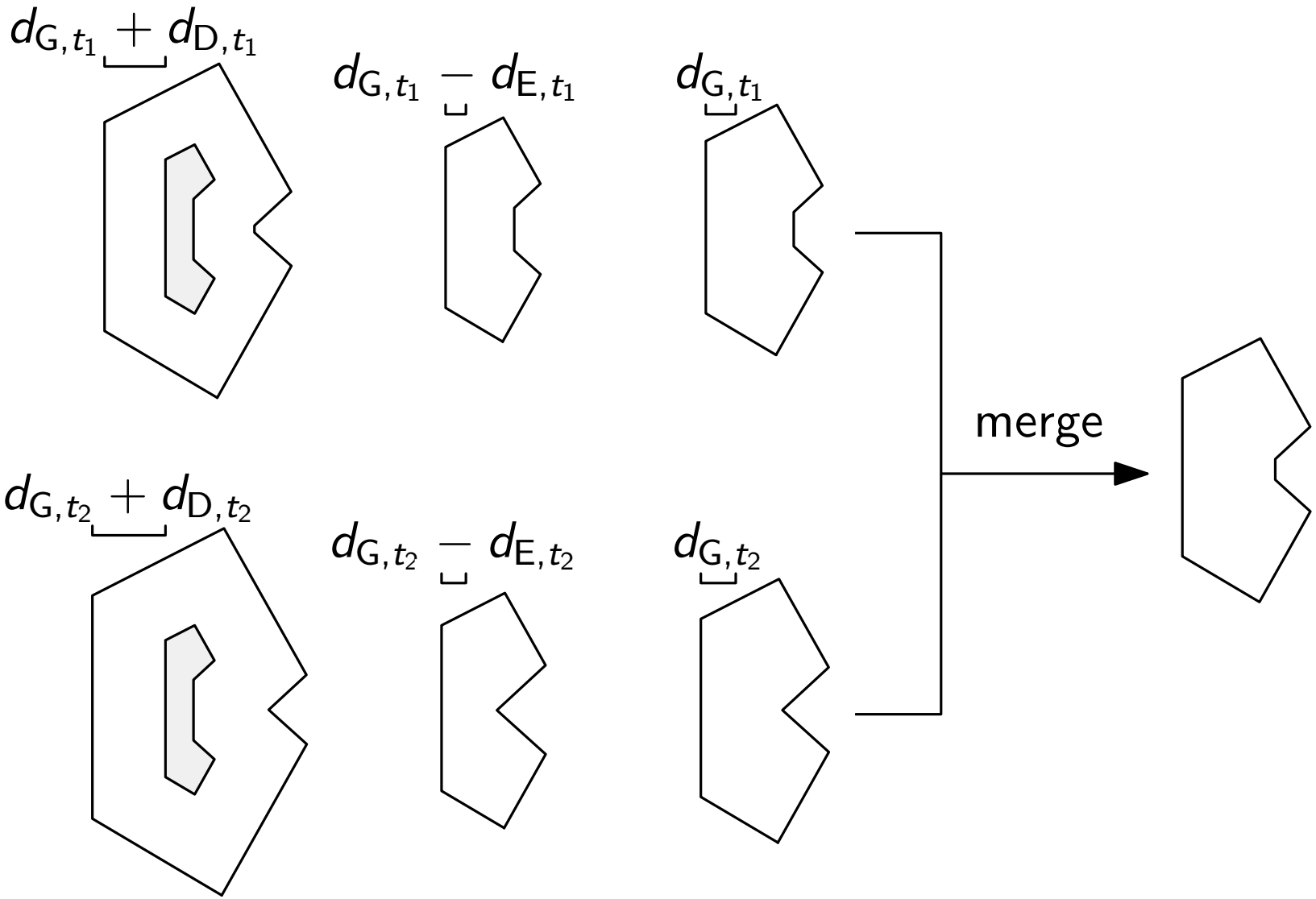

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A building may shrink because of line simplification

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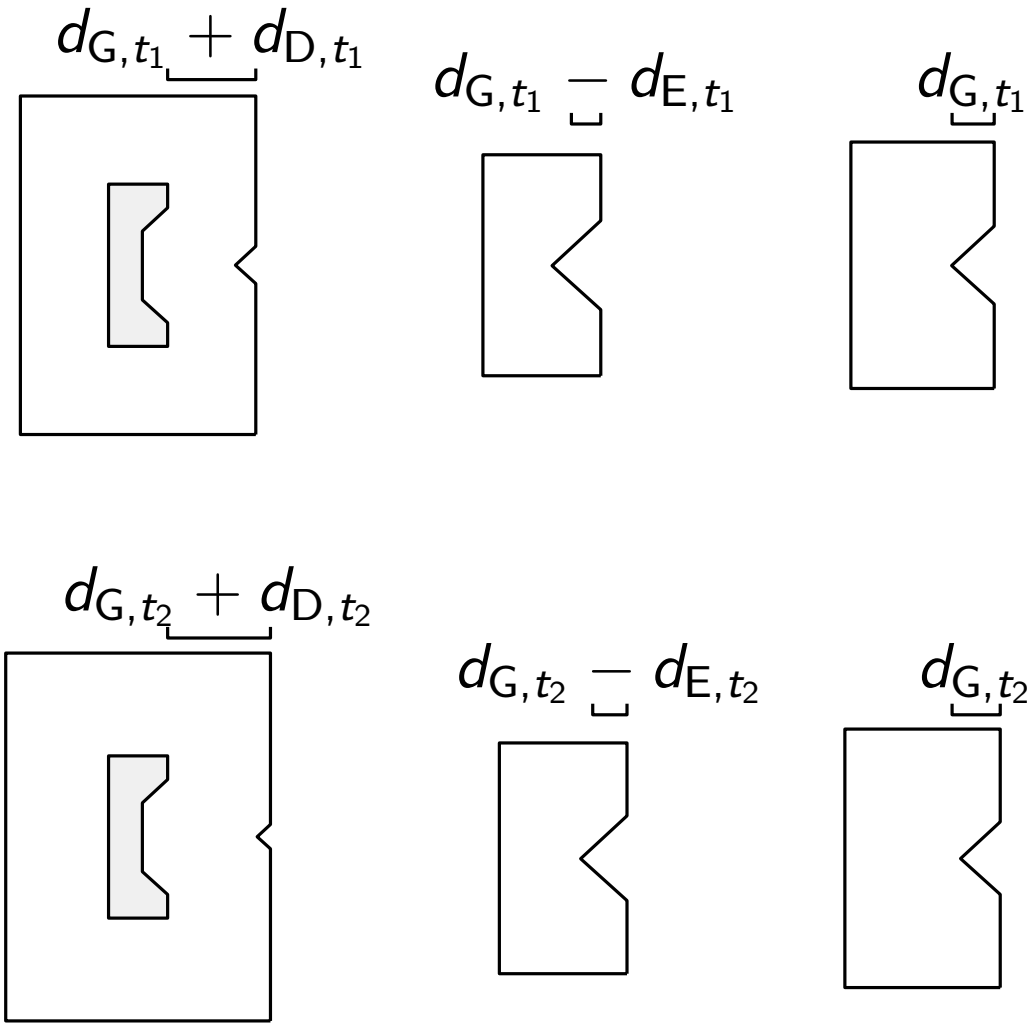

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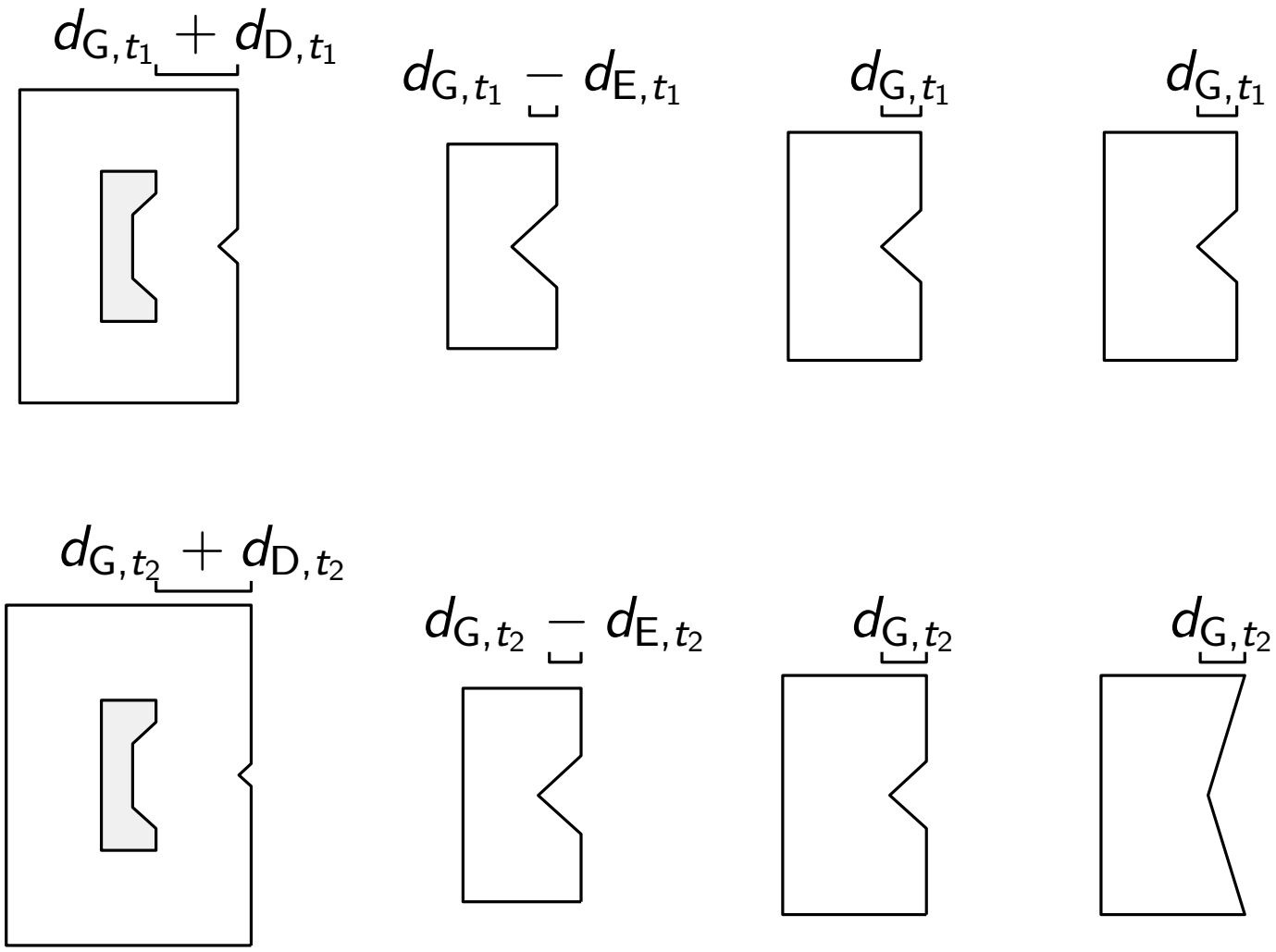

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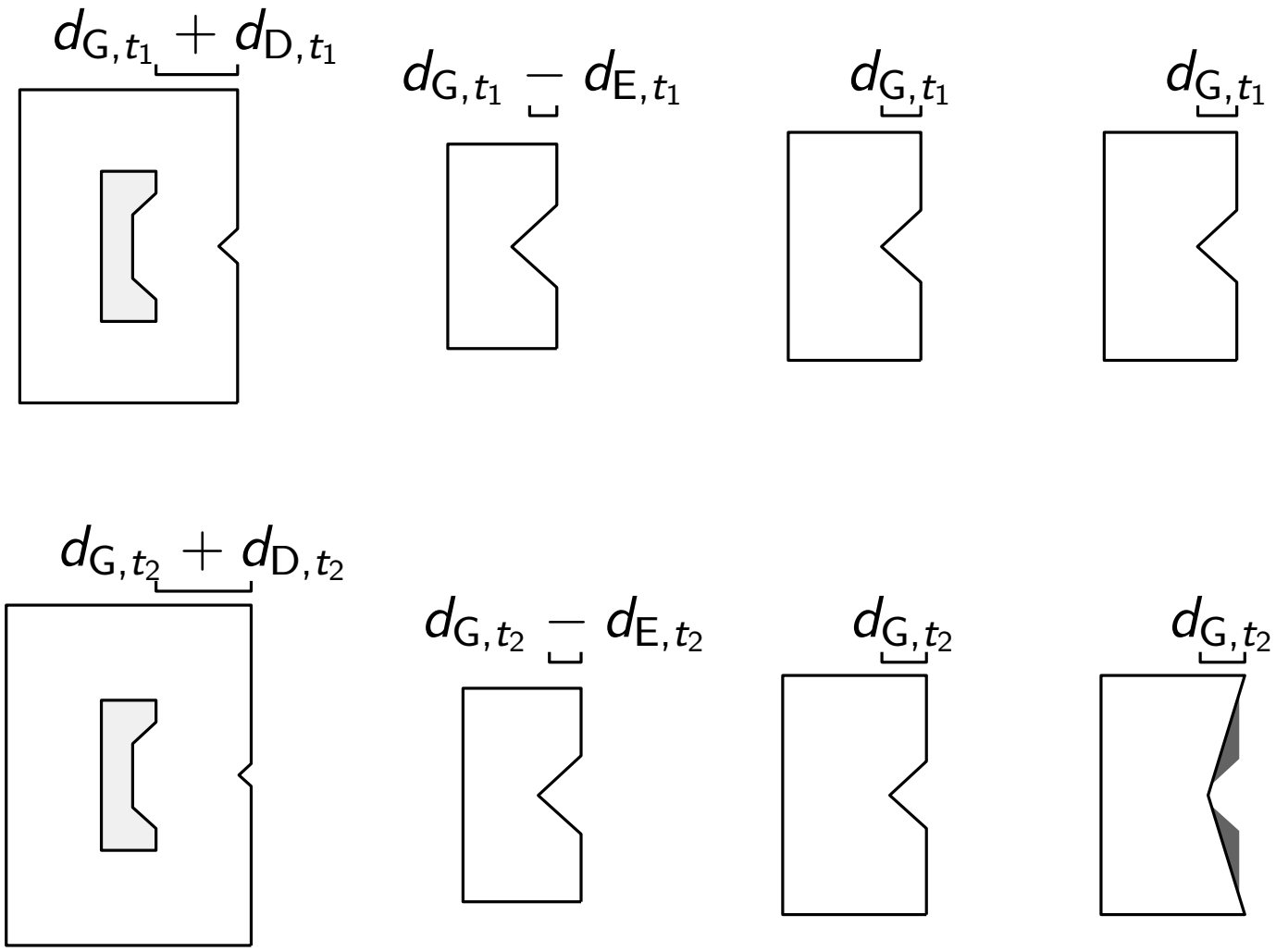

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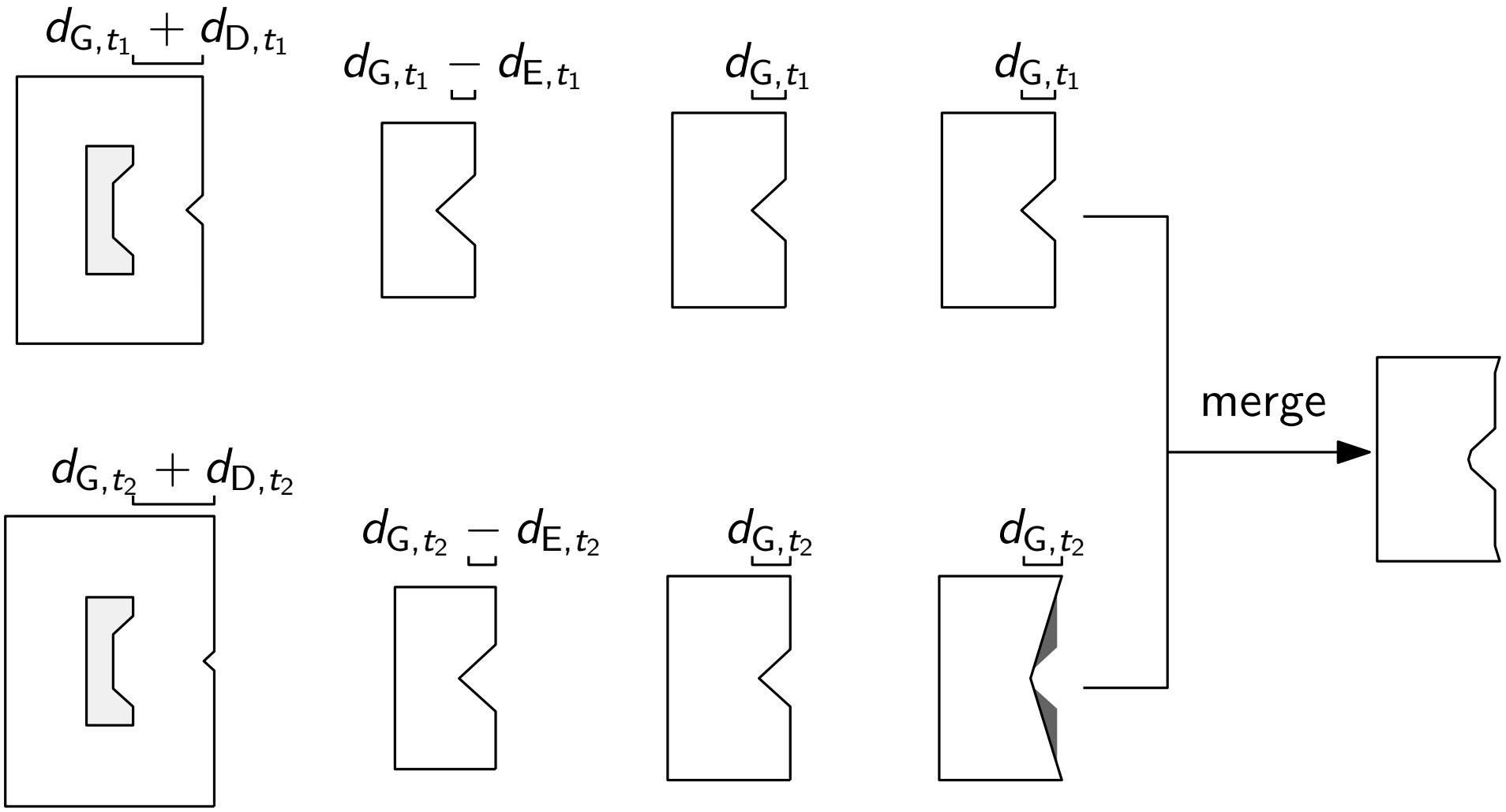
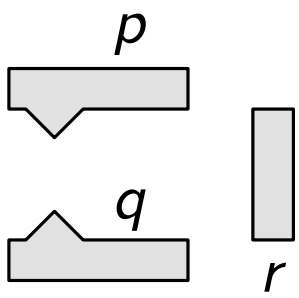


Merging avoiding shriking bridge



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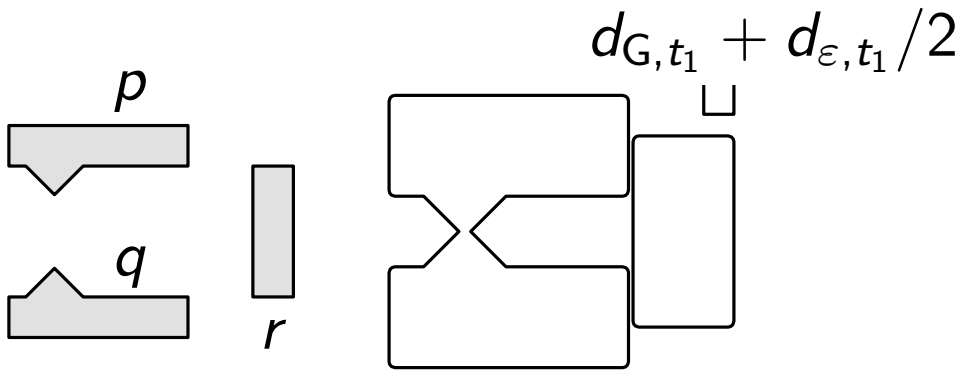

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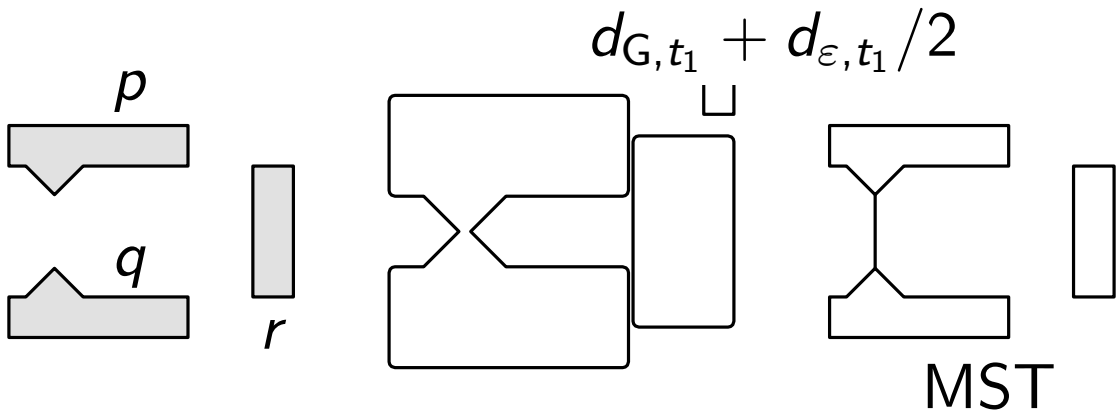

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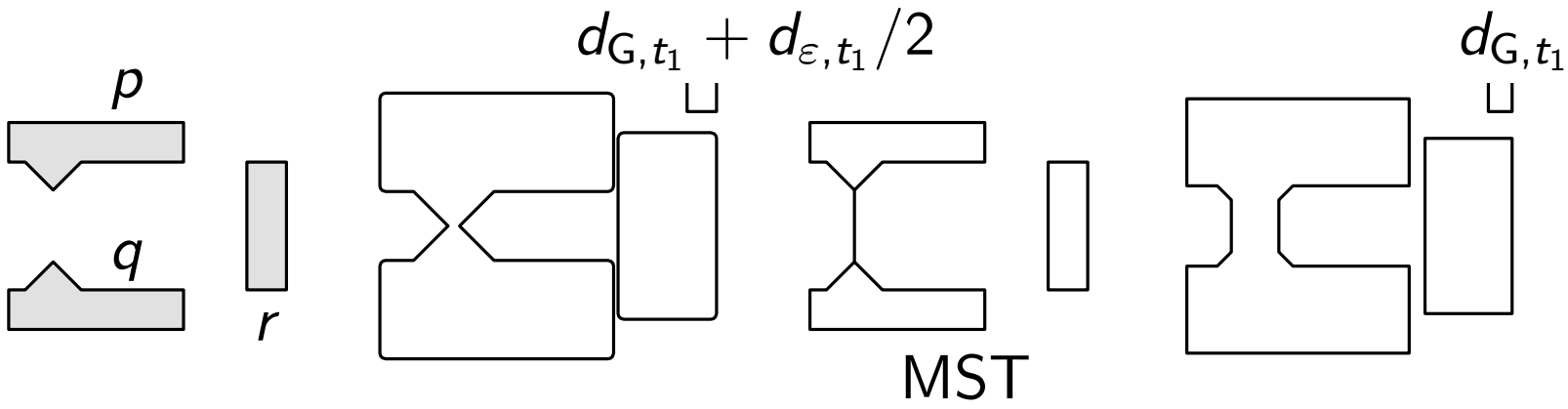

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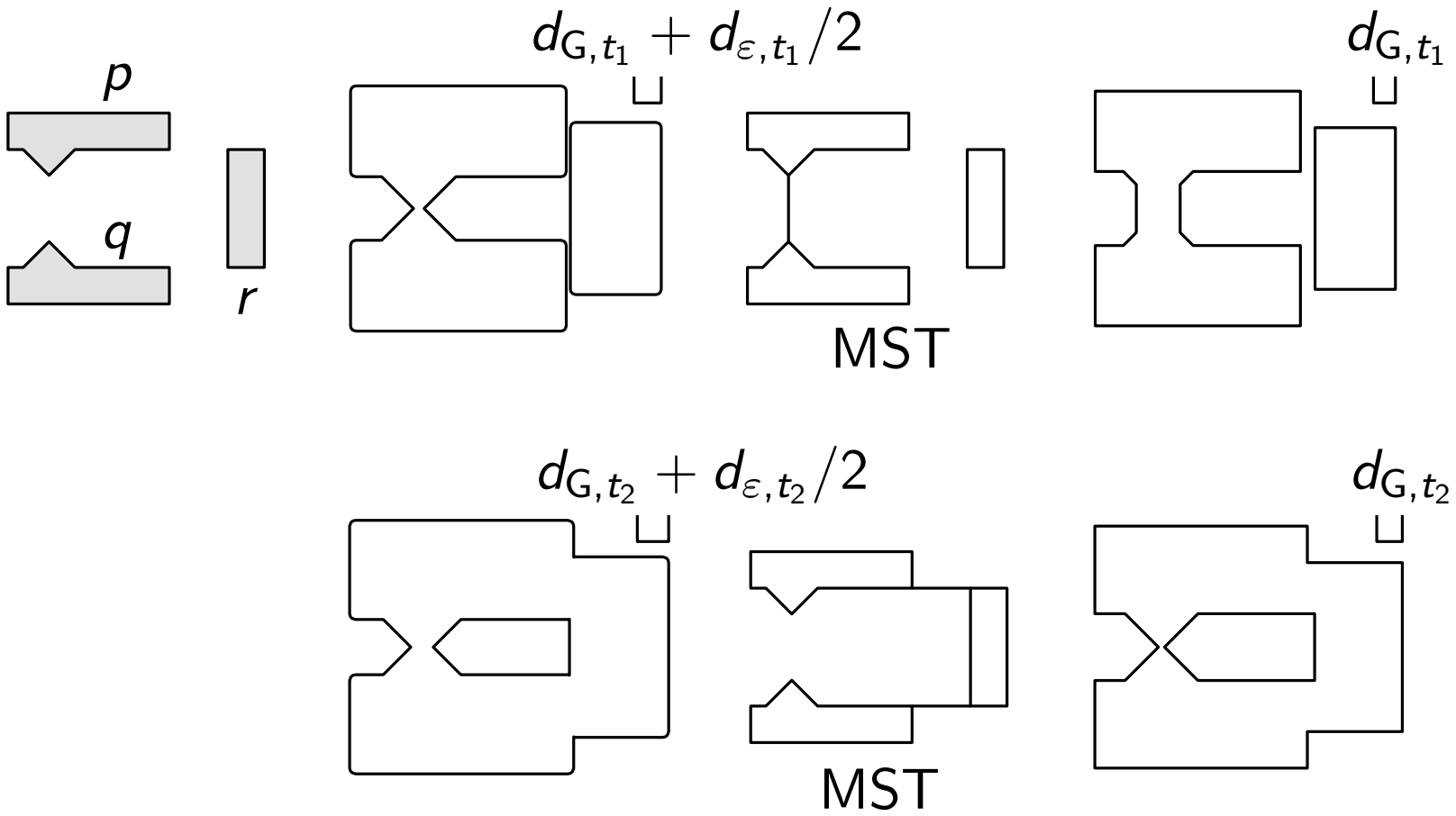

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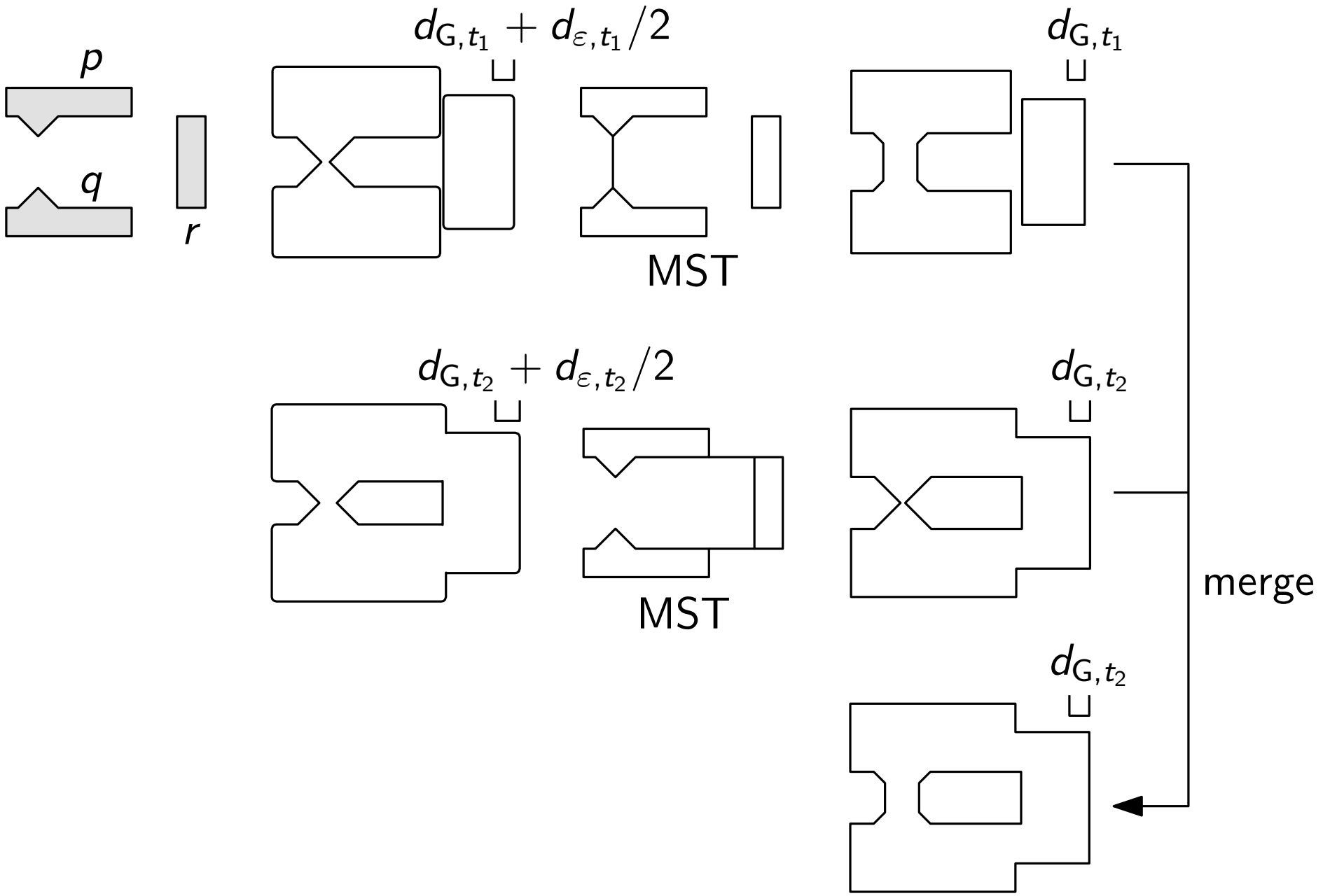

Clipping by Goal Shape

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

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In this way, we avoid that an intermeidate-scale results may exceed the goal shapes

Eliminating Small Buildings and Holes

- For a group building that will be aggregated at time $t = 1$, we eliminate them if their total area at any 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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- Removing a hole if its area is smaller than $a_{\text{h},t}$

$$a_{\text{h},t} = a_{\text{h}} \cdot M_t^2, \text{ where } a_{\text{h}} = 8\,\text{mm}^2$$

Running Time

- Operations like growing, dilation, eorsion, merge, and clip cost time $O(n^2)$. We may need to iteratively do $O(n)$ times, which increases our running time to $O(n^3)$
- Our version of Imai–Iri simplification algorithm takes time $O(n^3)$.

Outline

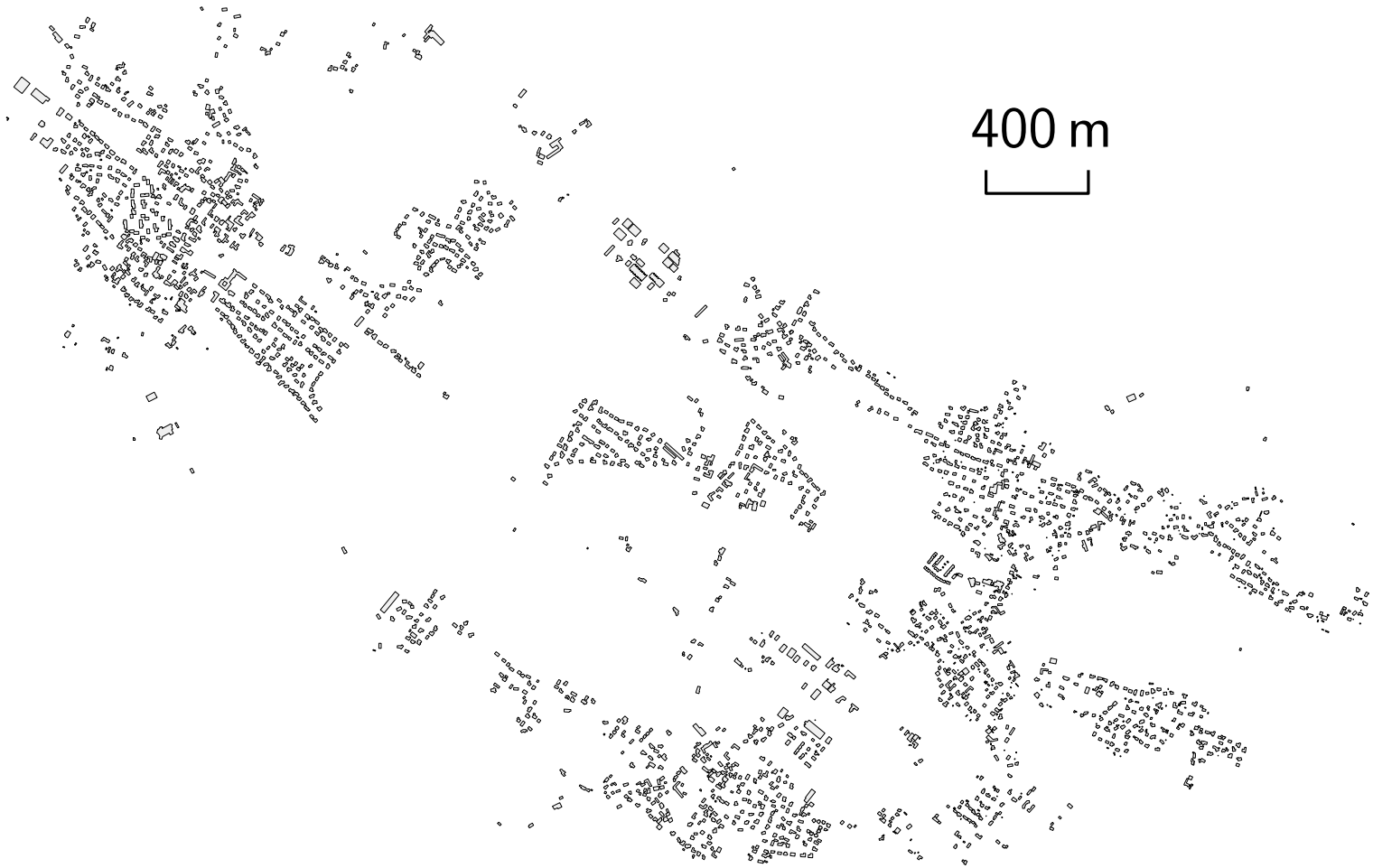
- Introduction
- Methodology
- Case Study
- Concluding Remarks

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 $d_G = 25\,\mathrm{m}$, and thus $d_{\mathrm{D},t} = t \cdot 35\,\mathrm{m}$ and $d_{\mathrm{E},t} = t \cdot 7.5\,\mathrm{m}$

Result

- 93.6 s for computing the goal shapes, where Imai–Iri algorithm simplifies 2,095 edges to 1,102 edges

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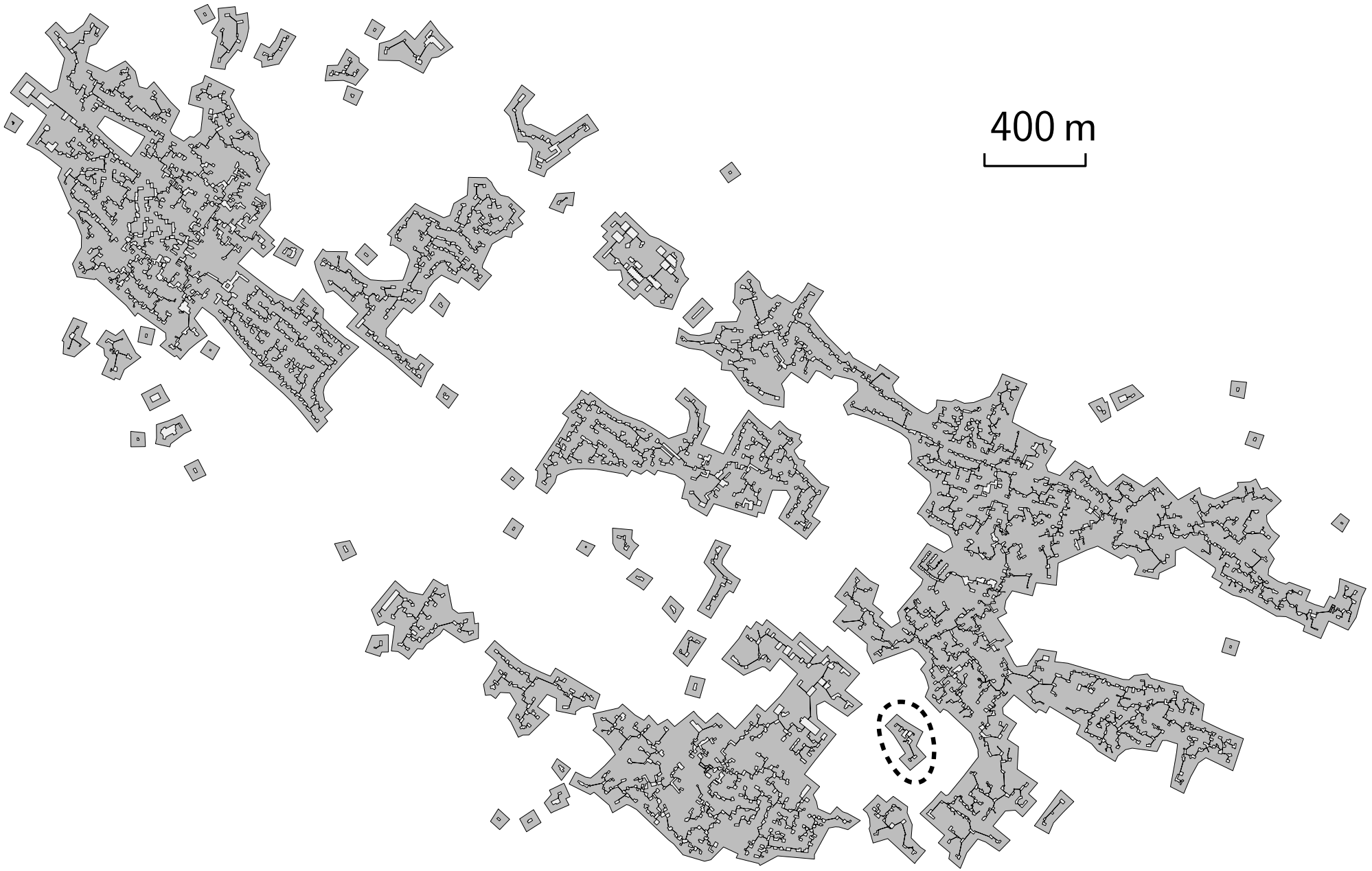
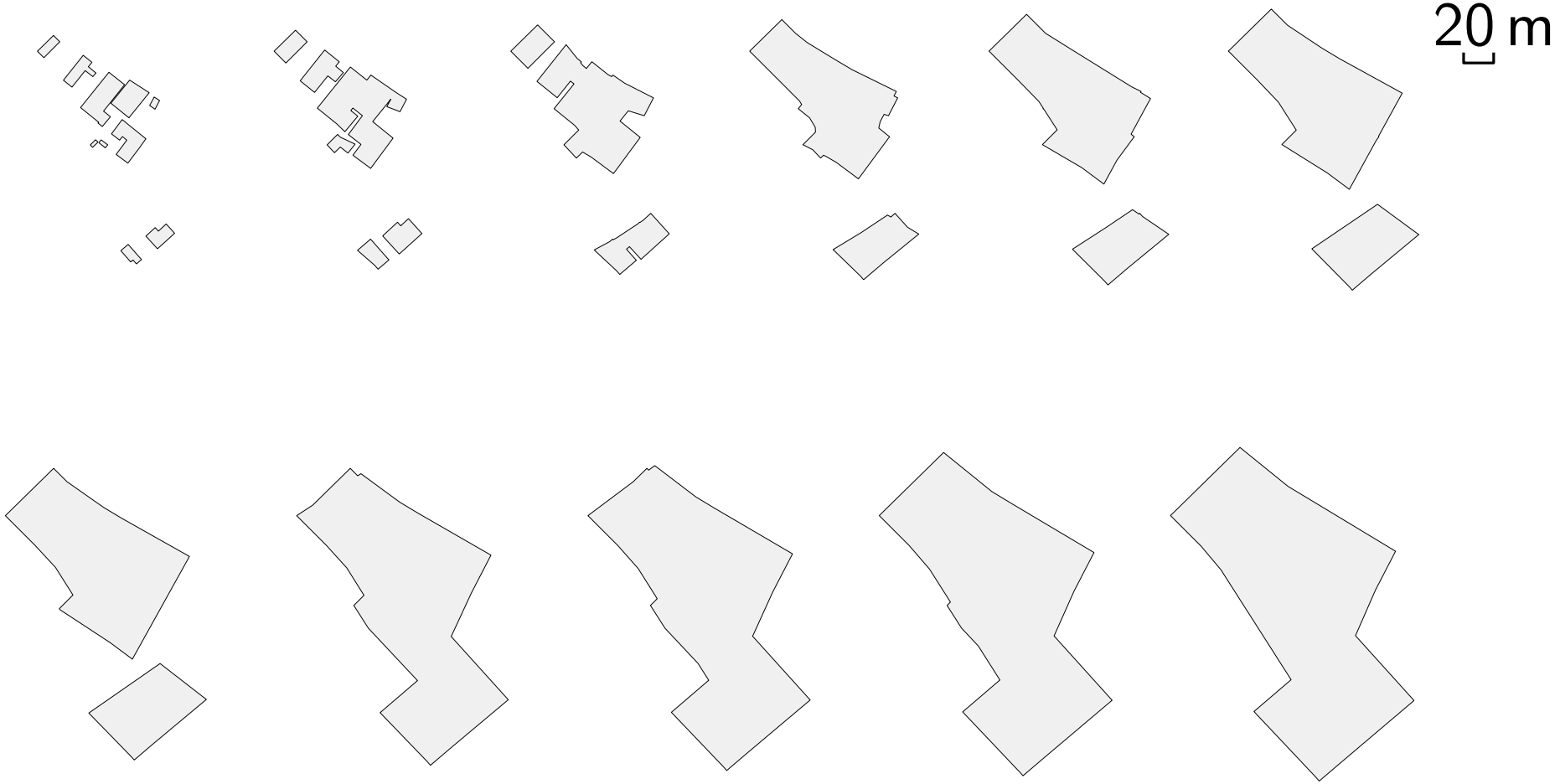
- 93.6 s for computing the goal shapes, where Imai–Iri algorithm simplifies 2,095 edges to 1,102 edges
- 668.2 s for computing a sequence of 10 maps


400 m

A sequence of maps



Outline

- Our Example Problem
- Methodology
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- Concluding Remarks

Concluding Remarks

Advantages of our method:

- The buildings grow continuously and are simplified.
- Right angles of buildings are preserved during growing
- Distances between buildings are larger than a specified threshold.

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Open problems:

- For a given map and scale, how many buildings should be kept after generalization?
- Again, how much total area of buildings should be kept? What about the total number of edges?
- How to design a meaningful user study to evaluate results?

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Thank you!

Looking for a postdoc position!