Improving the content of Vario-Scale Maps
An analysis into the generalization of border structures

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Topics

- Introduction & Motivation
- Theory & Related Work
- Methodology
- Implementation
- Results & Analysis
- Conclusions & Future Work

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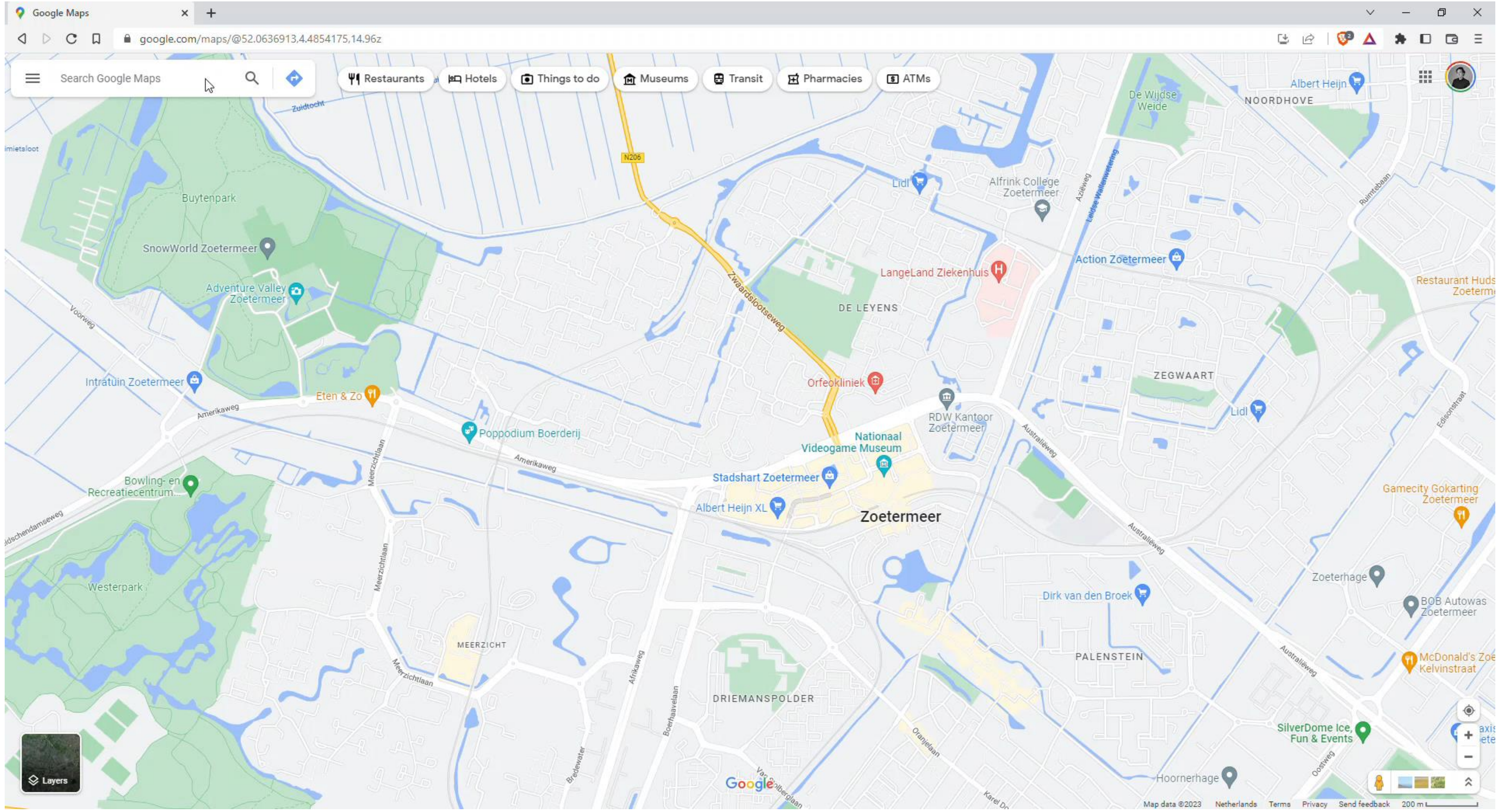
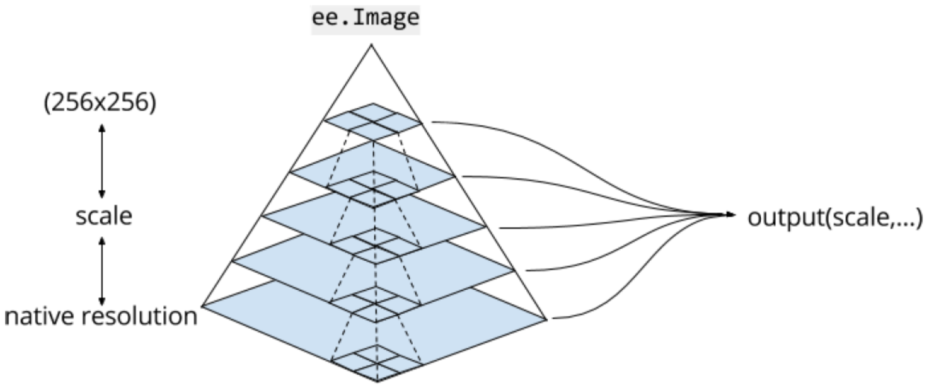
Motivation and Relevance





- From paper-based maps to `Multi-Scale` Digital Maps
- Pass decisions from cartographer to computer
- Can we guarantee it is correct?
- Vario-Scale alternative to Multi-Scale – But is that all?

Main Research Question

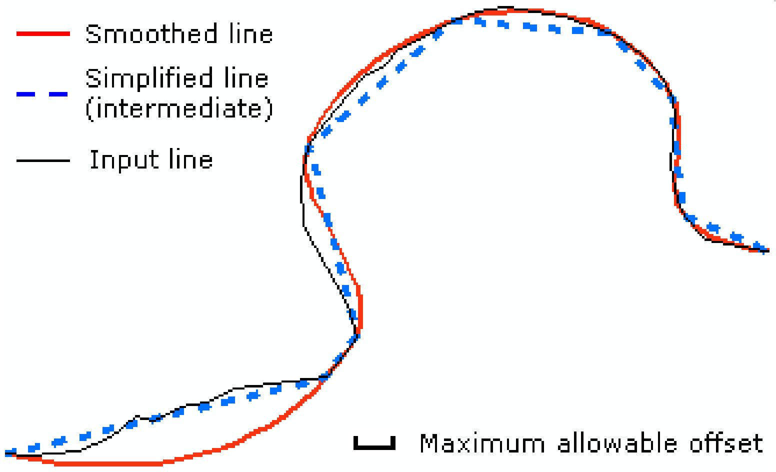
To what extent can multiple line-generalization algorithms be (simultaneously) introduced in the Vario-Scale structure such that they preserve the topology and enable an optimal line density (while trying to preserve the characteristics of the initial shape as well).

Breakdown of Main Research Question

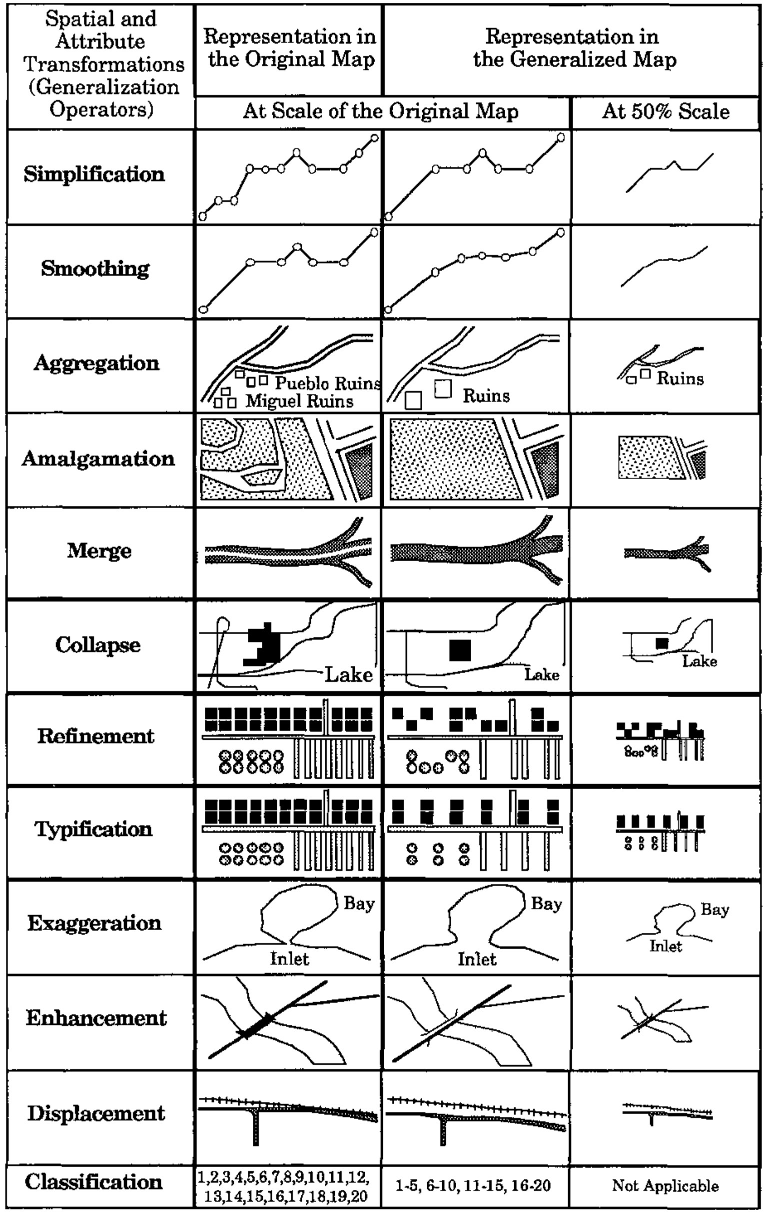
- Line Generalization theoretical questions
  - Which *line generalization algorithms* are better suited for which *particular situations*?
  - What is the *most suitable way* of combining said algorithms such that it *upholds the technical requirements*?
- Implementation related issues
  - What are the *conditions* and the *development requirements* necessary for *maintaining topological correctness* at *any scale*?
  - What is the optimal way of performing operations such that the line/vertices density remains constant, also when taking into account the scale change and its most favorable ratio between the number of objects and the size of the map which is being displayed at that particular scale?
  - How can the scale transition be performed in a smooth manner when integrating it into the broader Vario-Scale system? At the same time, what is the best way, from the point of view of time and size complexity (from the perspective of Big O notation concepts, when looking conceptually at the efficiency of the various algorithms), to perform line generalization in particular and Vario-Scale operations in general?

Generalization – Big Picture

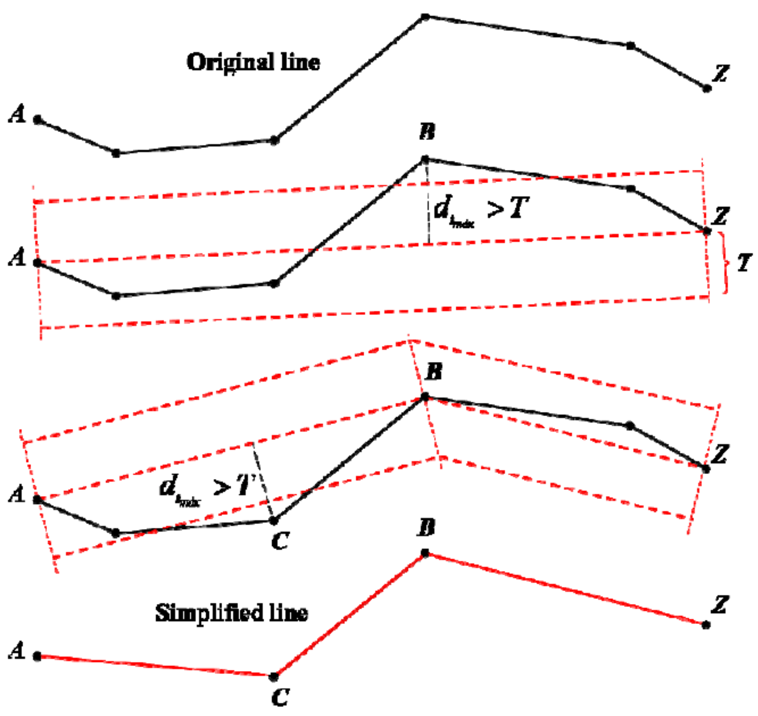
Cartographic Generalization [DEFINITION] = the process of abstracting, in a meaningful way, the diversity and complexity of the real world such that the resulting cartographic representation is useful and usable with respect to the given scale and overall purpose of the map.



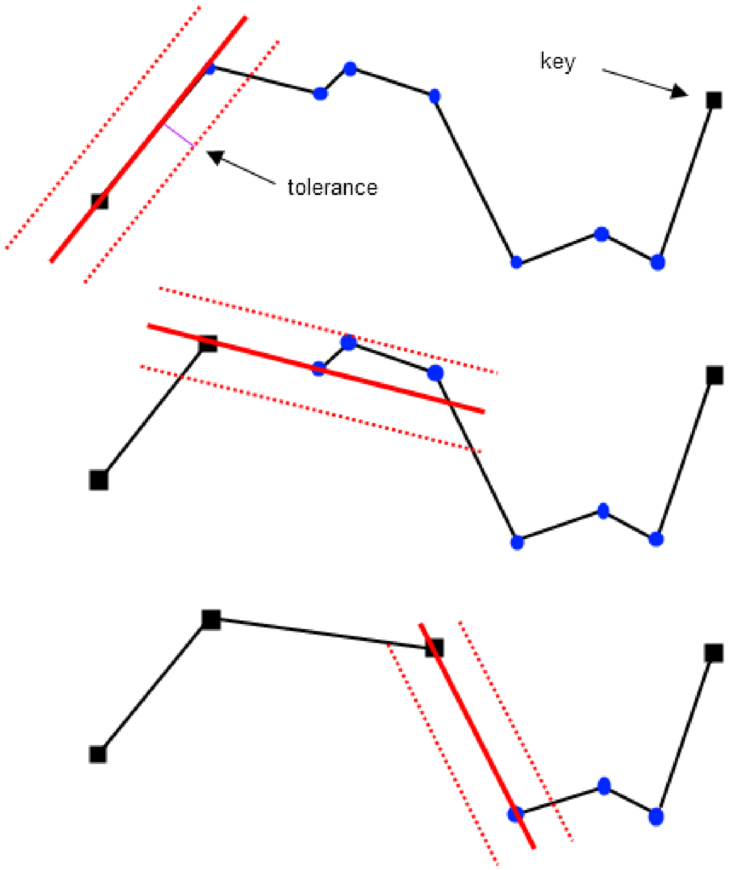
Line Generalization Approaches:
- Smoothing
- Simplification



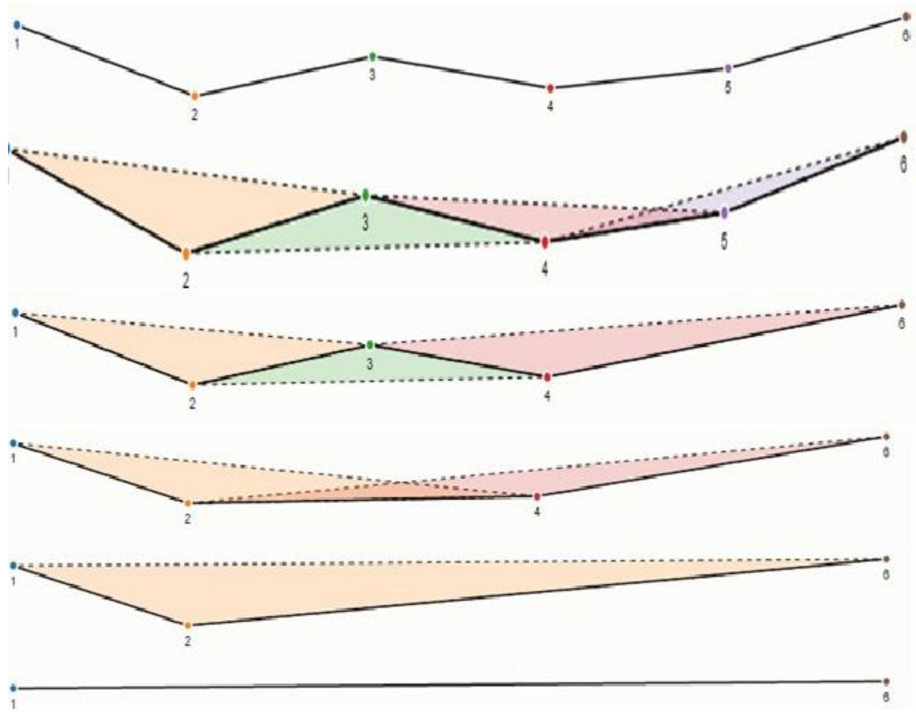
Line Generalization in-depth concepts – DP, RW and VW



Douglass-Peucker

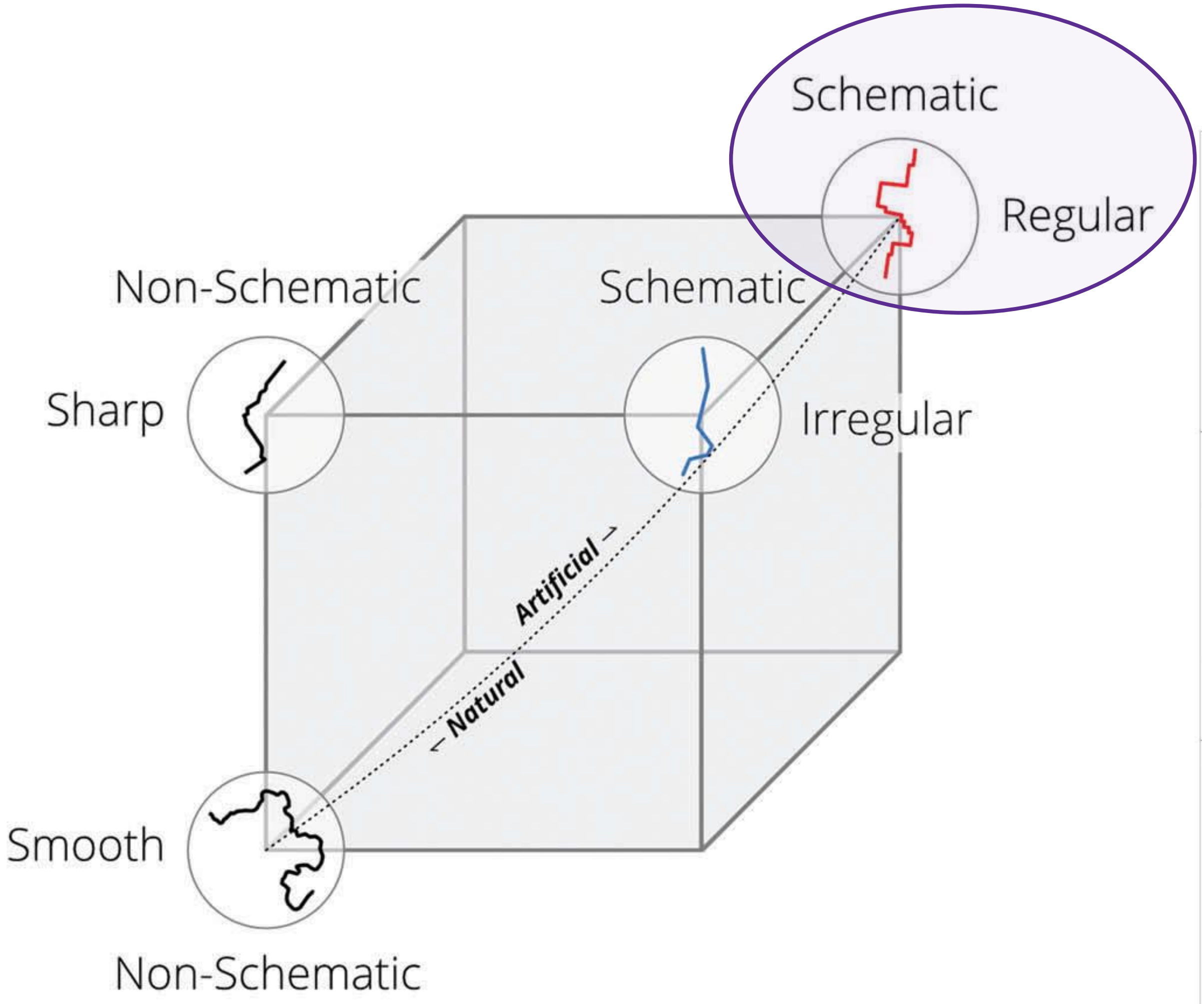


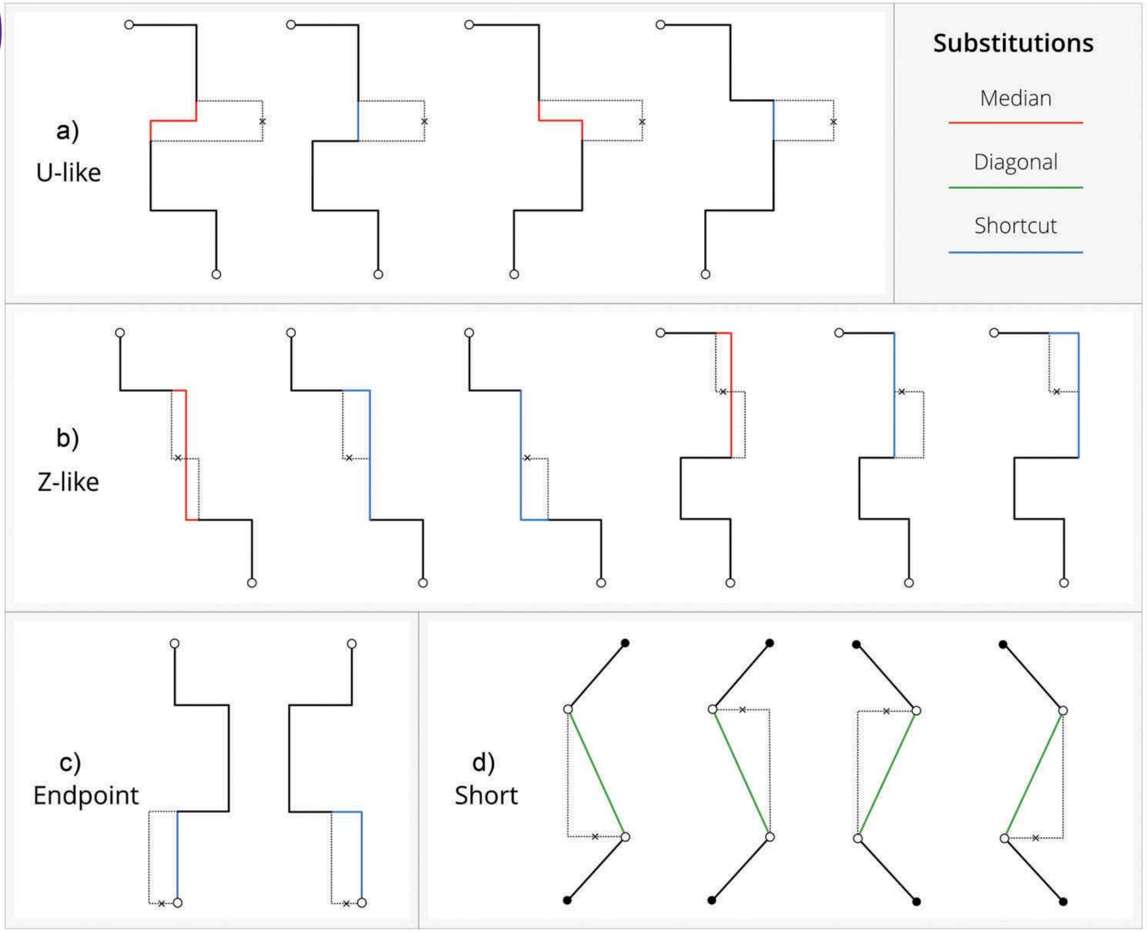
Reumann-Witkam



Visvalingam–Whyatt

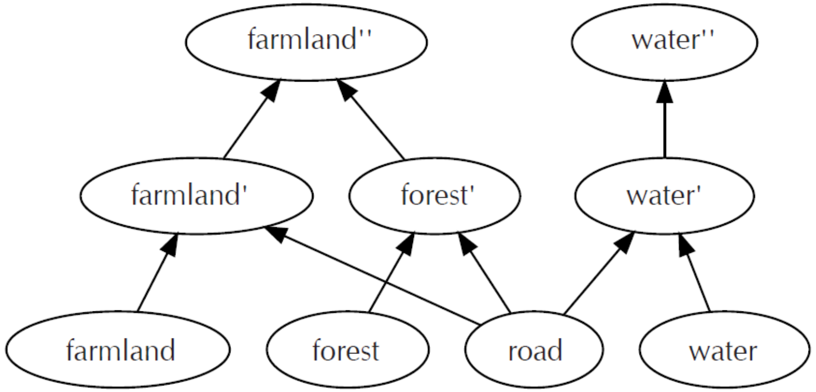
Line Generalization in-depth concepts – Samsonov-Yakimova



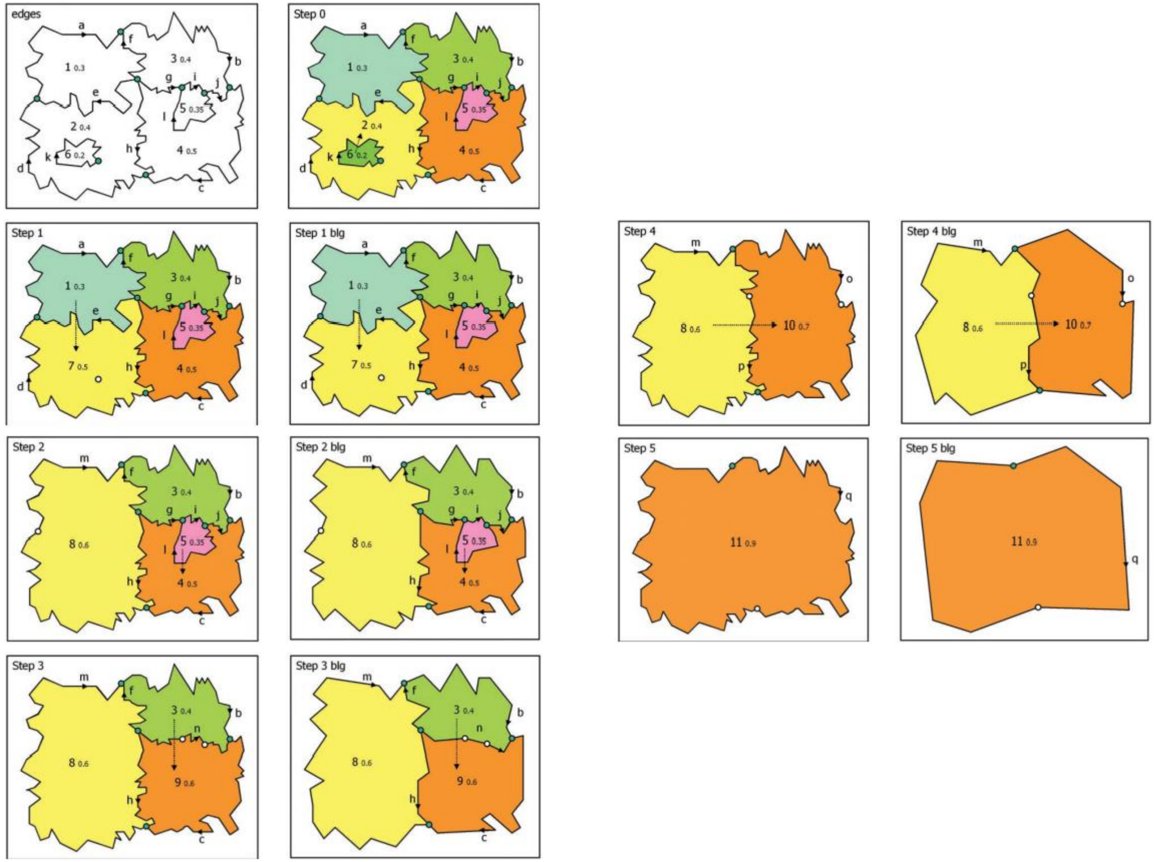


Vario-Scale Maps – the tGAP Structure

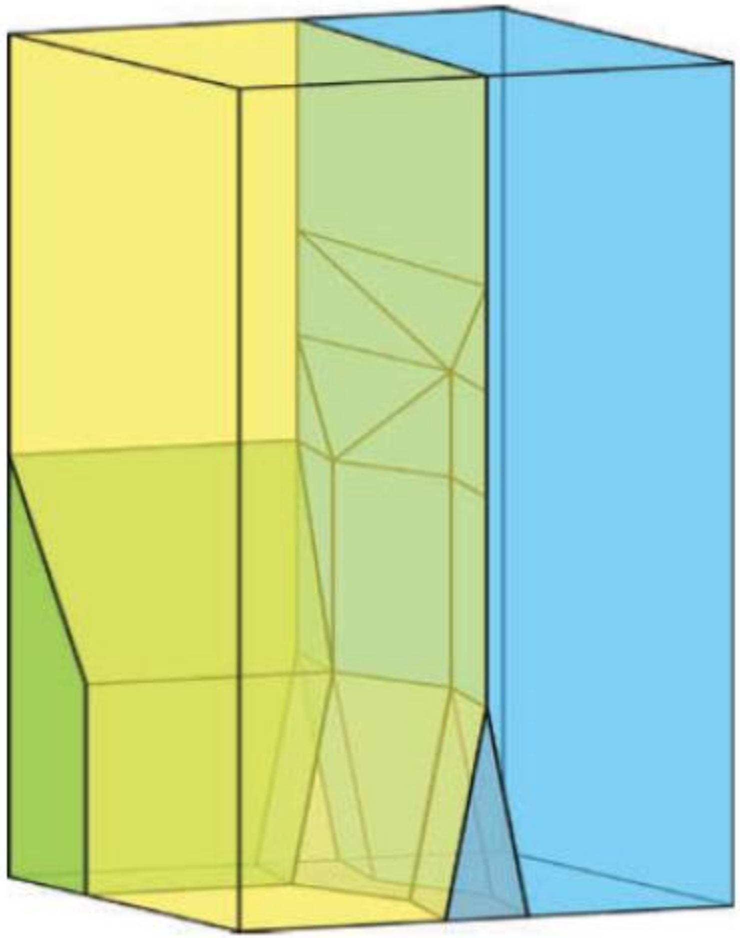
(a) Original map *(b) Result of collapse* *(c) Result of merge* *(d) Result of simplify*



(e) Corresponding tGAP structure



Vario-Scale Maps – SSC and Topological Structure

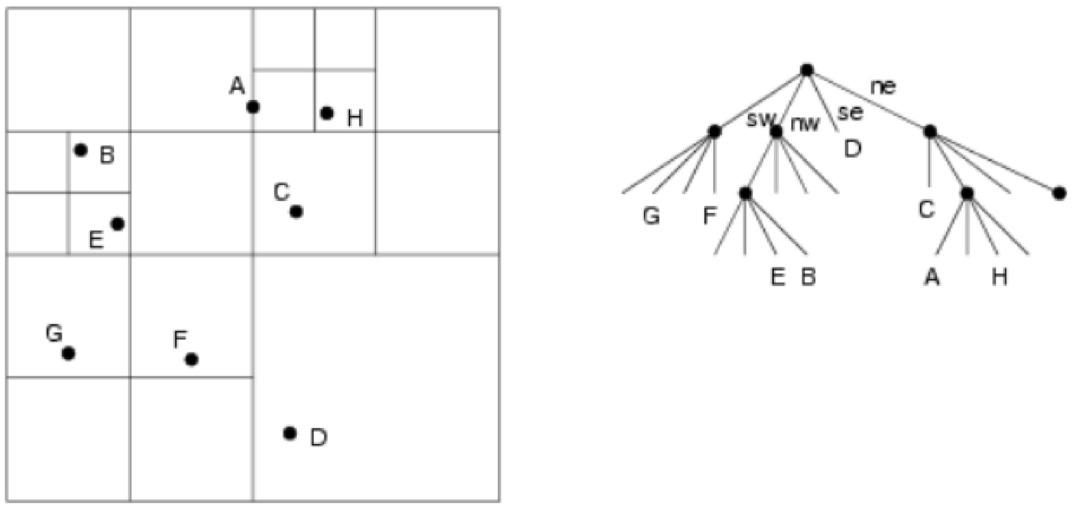


Planar Partition [DEFINITION] = a subdivision of a polygonal subset of the plane into non-overlapping polygons

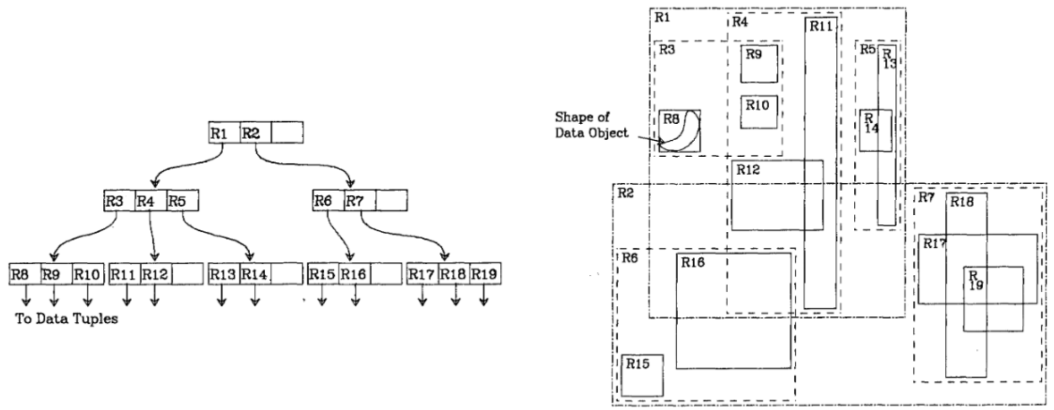
Planar Partition requirements:

- Completeness
- Correctness
- One node multiple edges principle
- (Extra) each partition should be classified

Spatial Data Structures

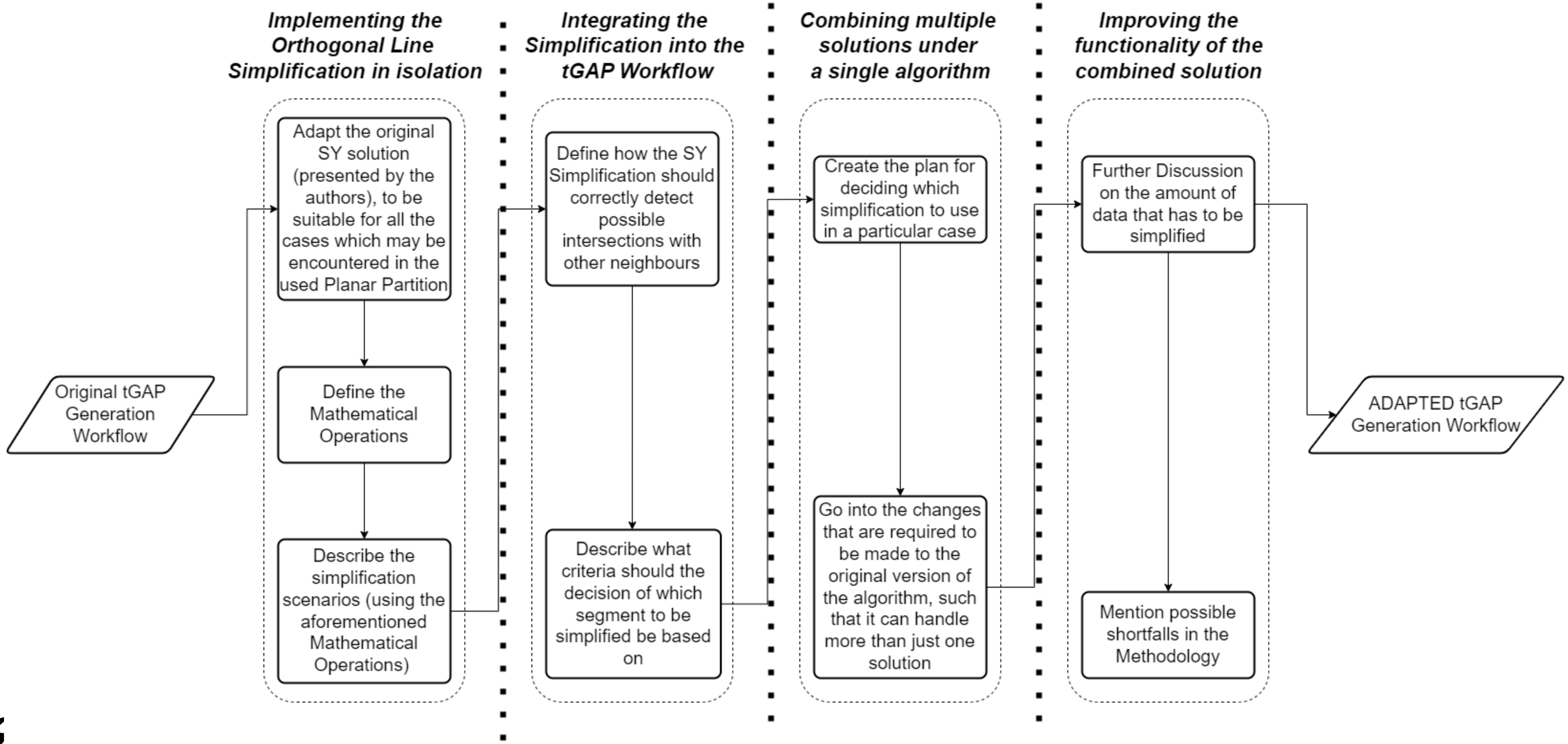


PR-Quadtree



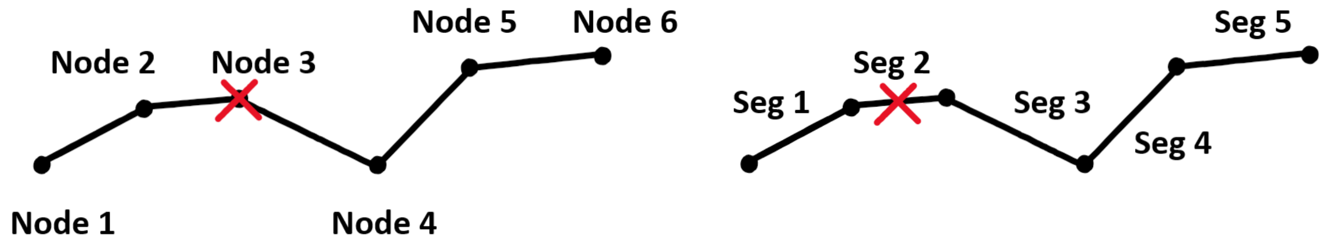
R-tree

Methodology Diagram

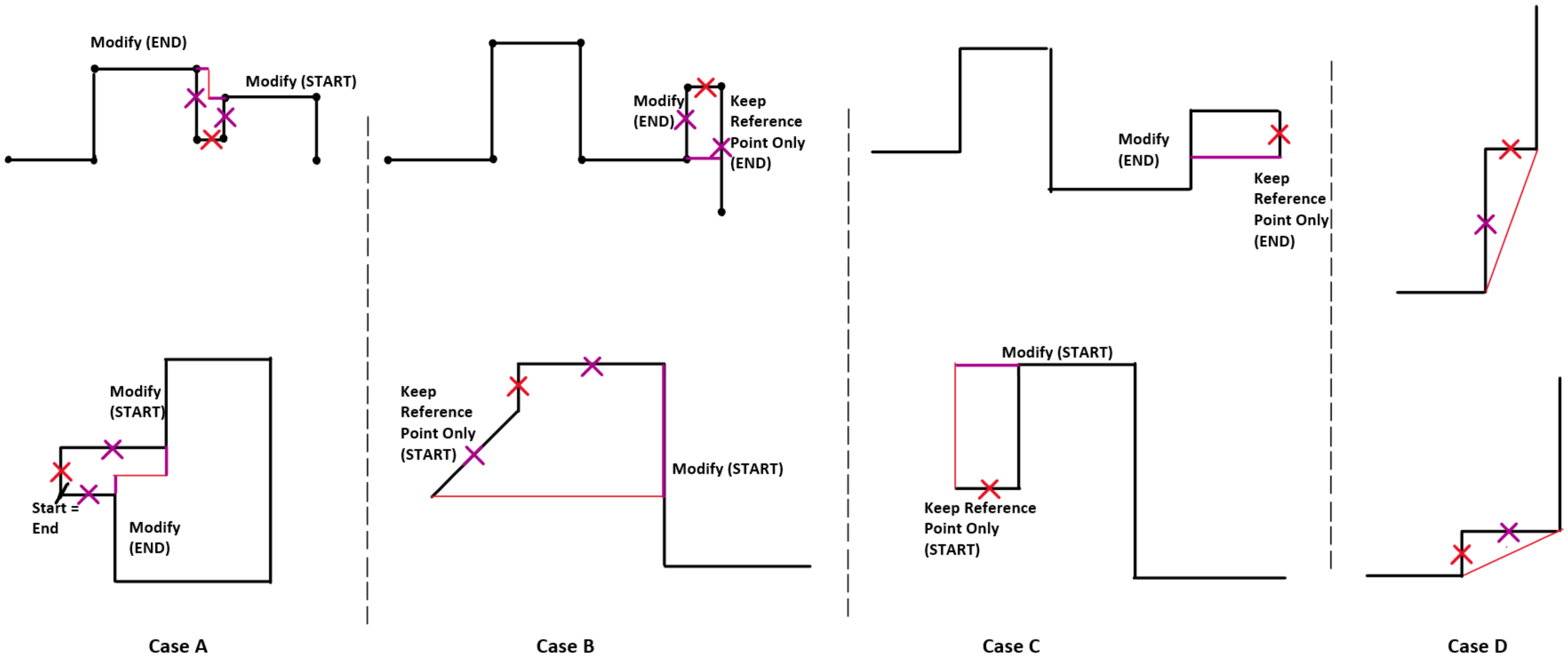


Samsonov-Yakimova in Isolation – Initial Definition and Classification

- Focus no longer on Nodes, but on Edges



- Ensure geometric structure is correct
- If algorithm can be applied, then classify the situation



Samsonov-Yakimova in Isolation – Segments – Operations and Definitions

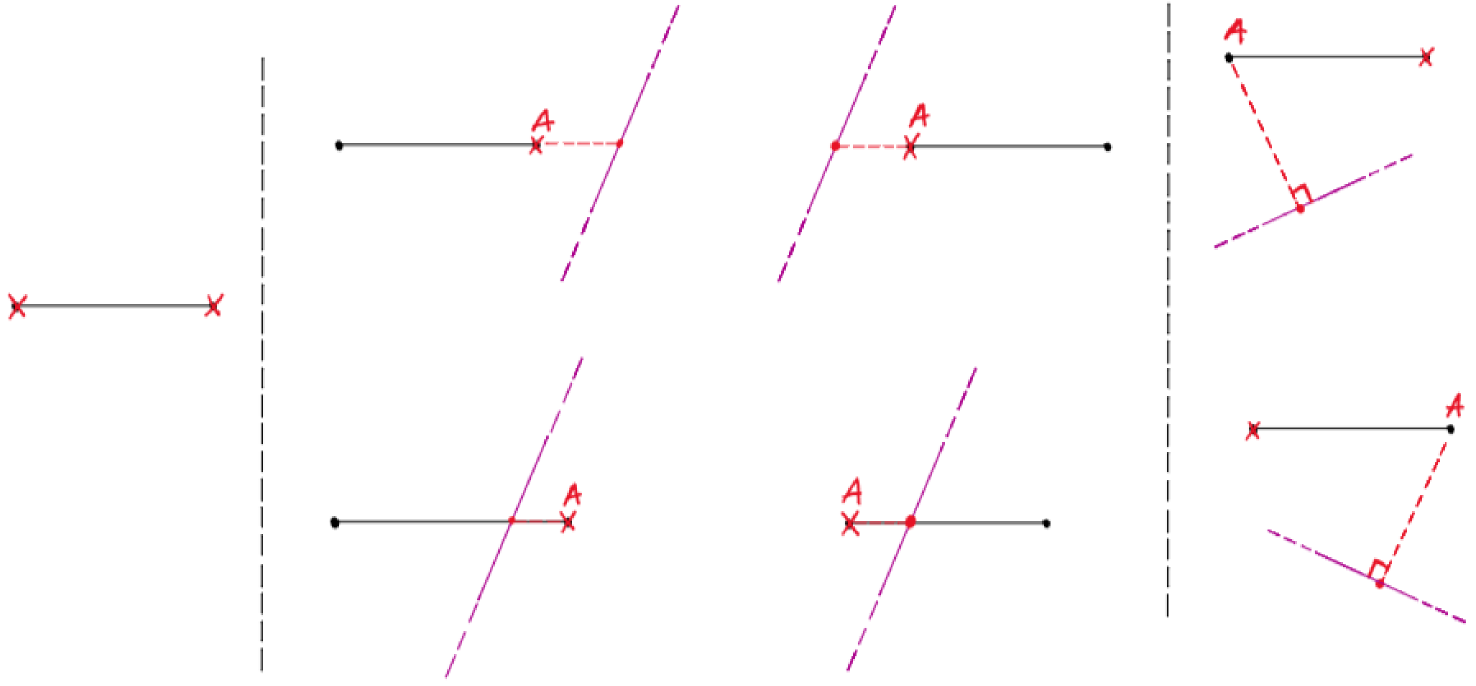
Possible Operations:
- Complete removal
- Modification
- Keep Reference Points Only

Determining the equation of the segments, based on their extremity nodes (P1(x1,y1), P2(x2,y2)):

$$\text{Slope: } \mathbf{m} = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)$$

$$\text{Y-intercept: } \mathbf{b} = y1 - m * x1 = y2 - m * x1$$

$$\text{Final Line equation: } \Rightarrow y = \mathbf{m} * x + \mathbf{b}$$



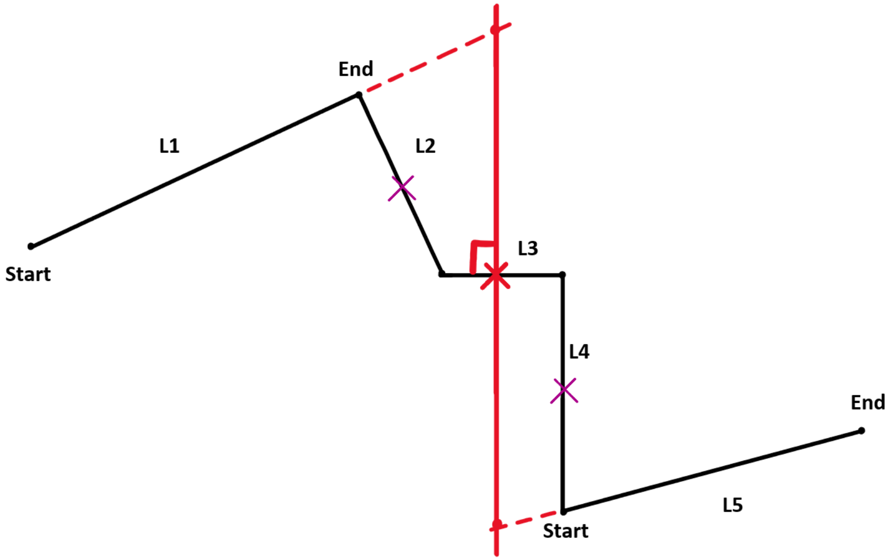
Complete Removal

Modification
Left - Anchor point - End
Right - Anchor point - Start

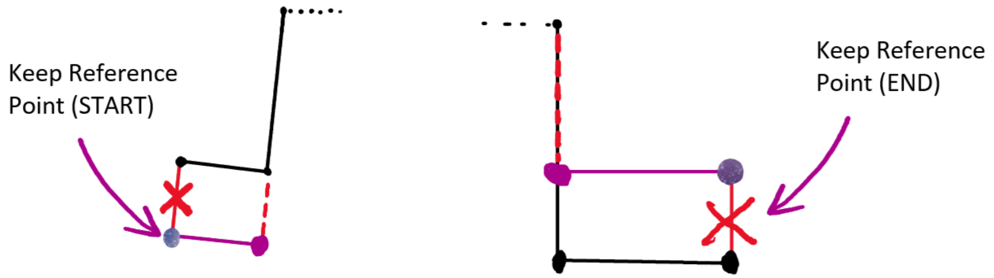
Keep Anchor Point Only
Top - Anchor point - Start
Bottom - Anchor point - End

Samsonov-Yakimova in Isolation – Focus on Types of Operations

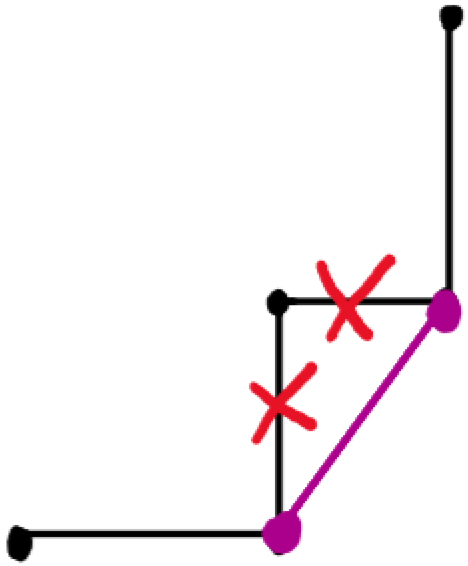
Median



Diagonal

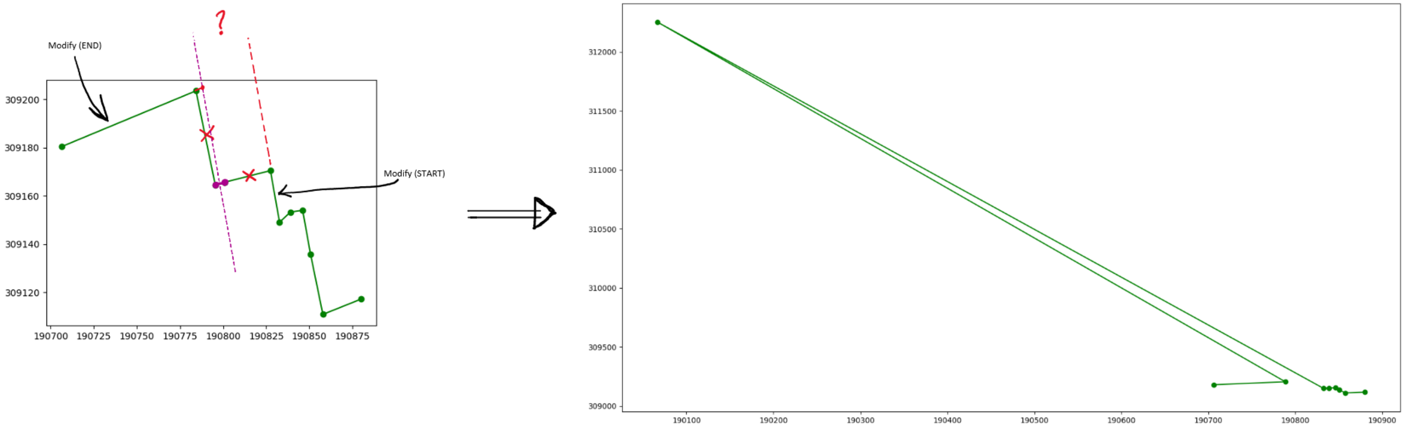


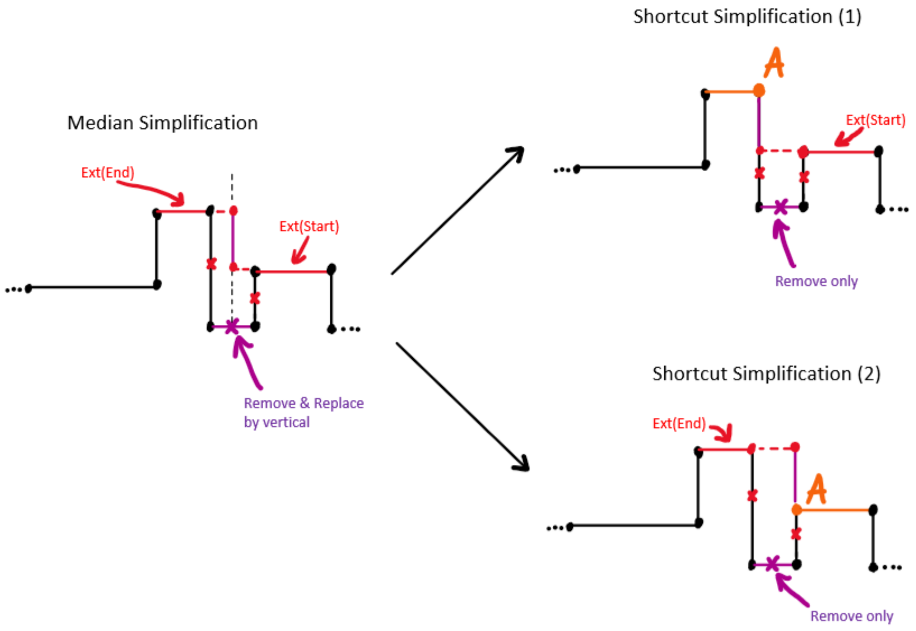
Shortcut

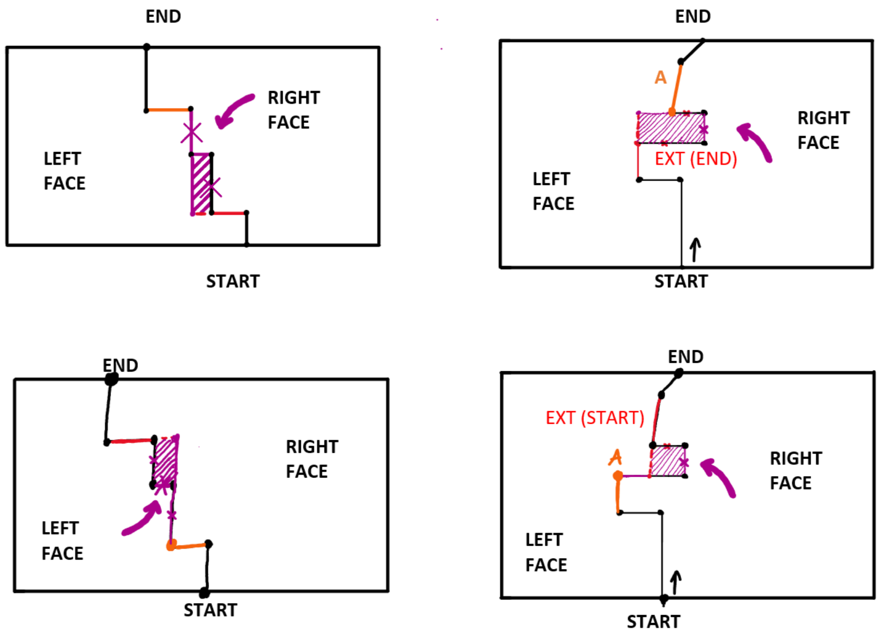


Samsonov-Yakimova in Isolation – Topological Inconsistancies & Alternatives

- Sometimes, due to the way a particular geometry is, the Median Simplification may cause issues -> Alternative Shortcut Simplification

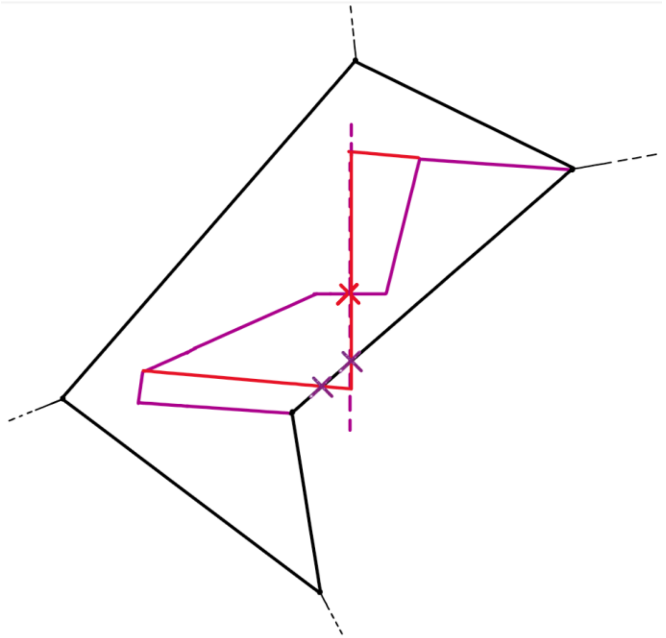


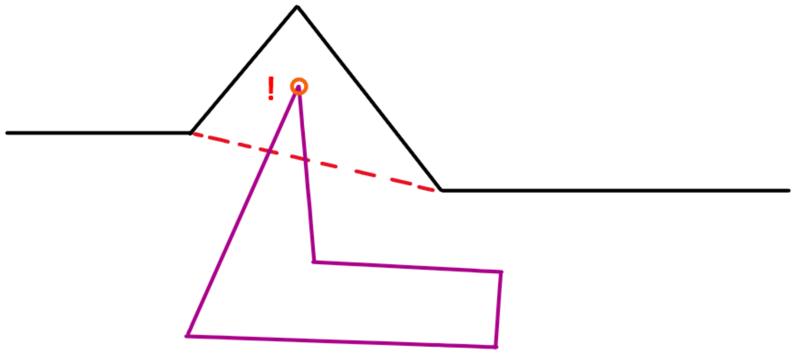


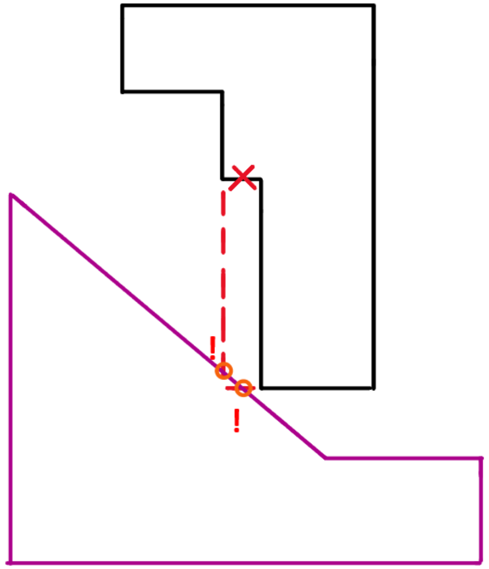


Integration in tGAP System

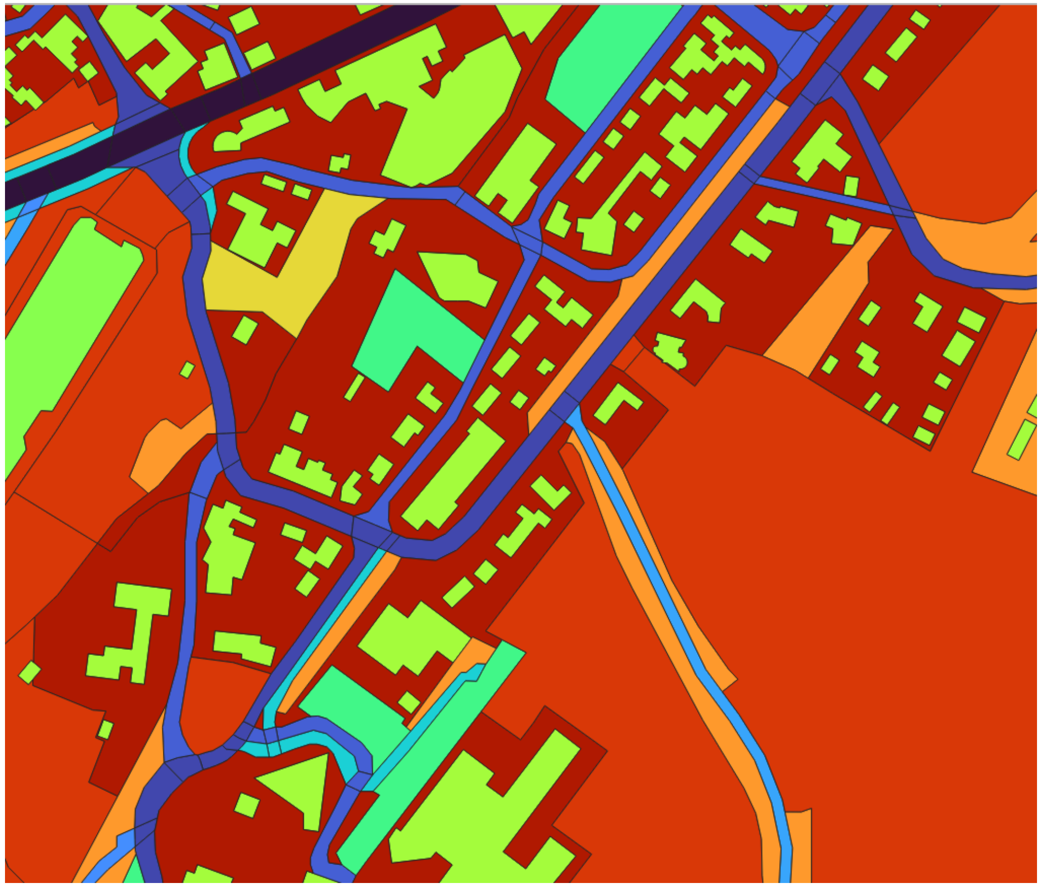
To keep in mind when designing a solution:
- Intersection with other neighbors
- How to decide which Edge to pick
- How to decide which Algorithm to choose







Combining multiple line generalization solutions into the tGAP System



From Object Classification…

Border between	Cls_1	Cls_2	...	Cls_n
Cls_1*	*Cls_1_cA*	f(1_cA, 2_cA)	...	f(1_cA, n_cA)
Cls_2*	f(2_cA, 1_cA)	*Cls_2_cA*	...	f(2_cA, n_cA)
...	...	...	...	...
Cls_n*	f(n_cA, 1_cA)	f(n_cA, 2_cA)	...	*Cls_n_cA*

To Compatibility Matrix

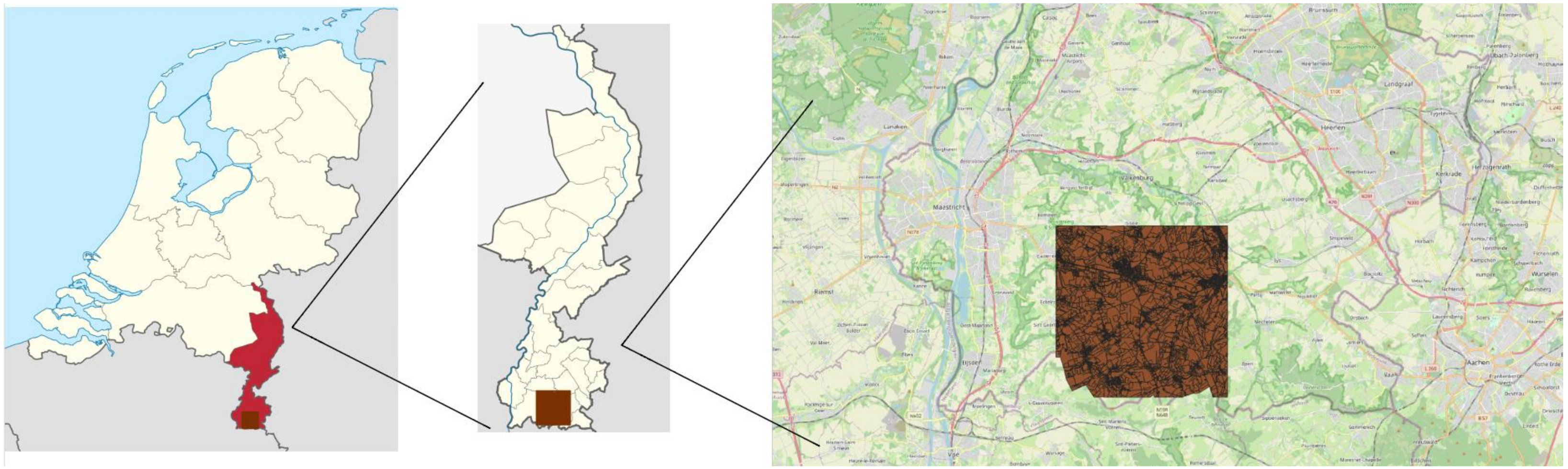
Software and Datasets

python™

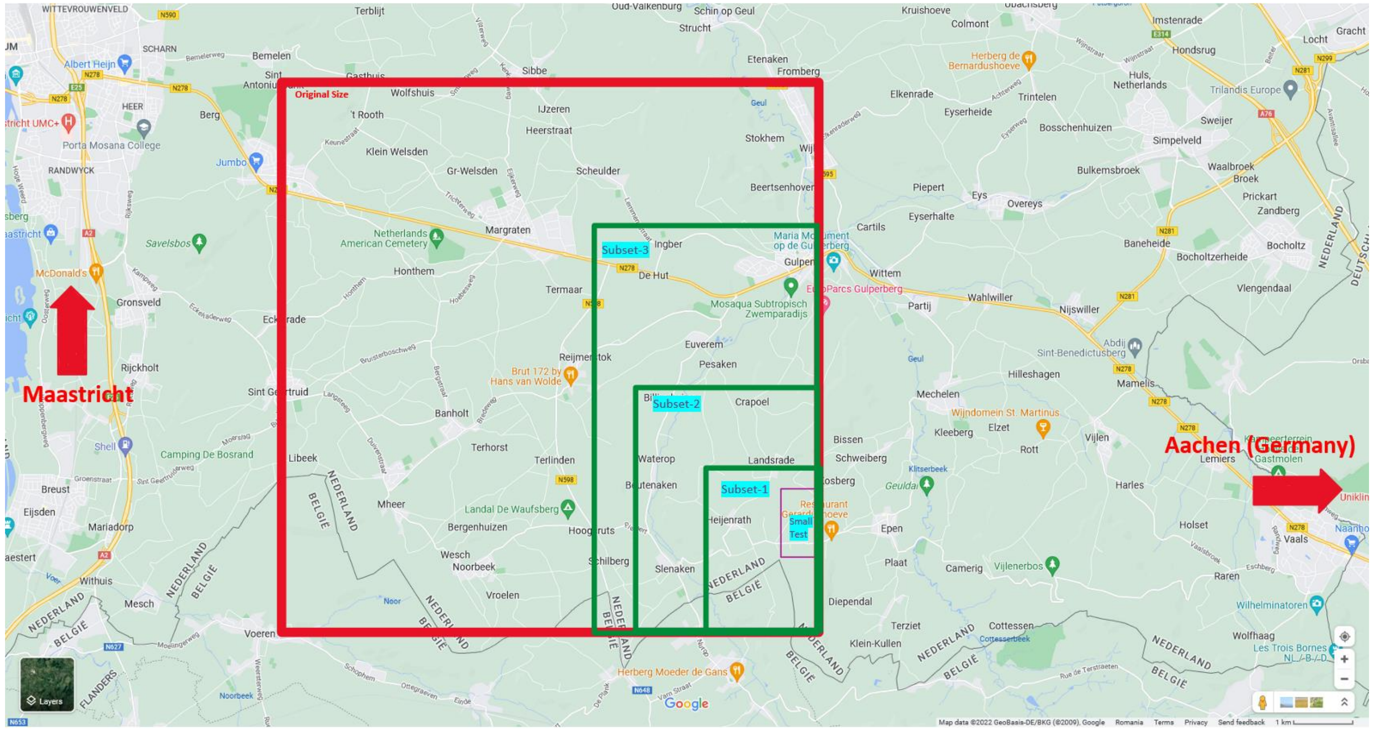
Shapely

QGIS

PostgreSQL

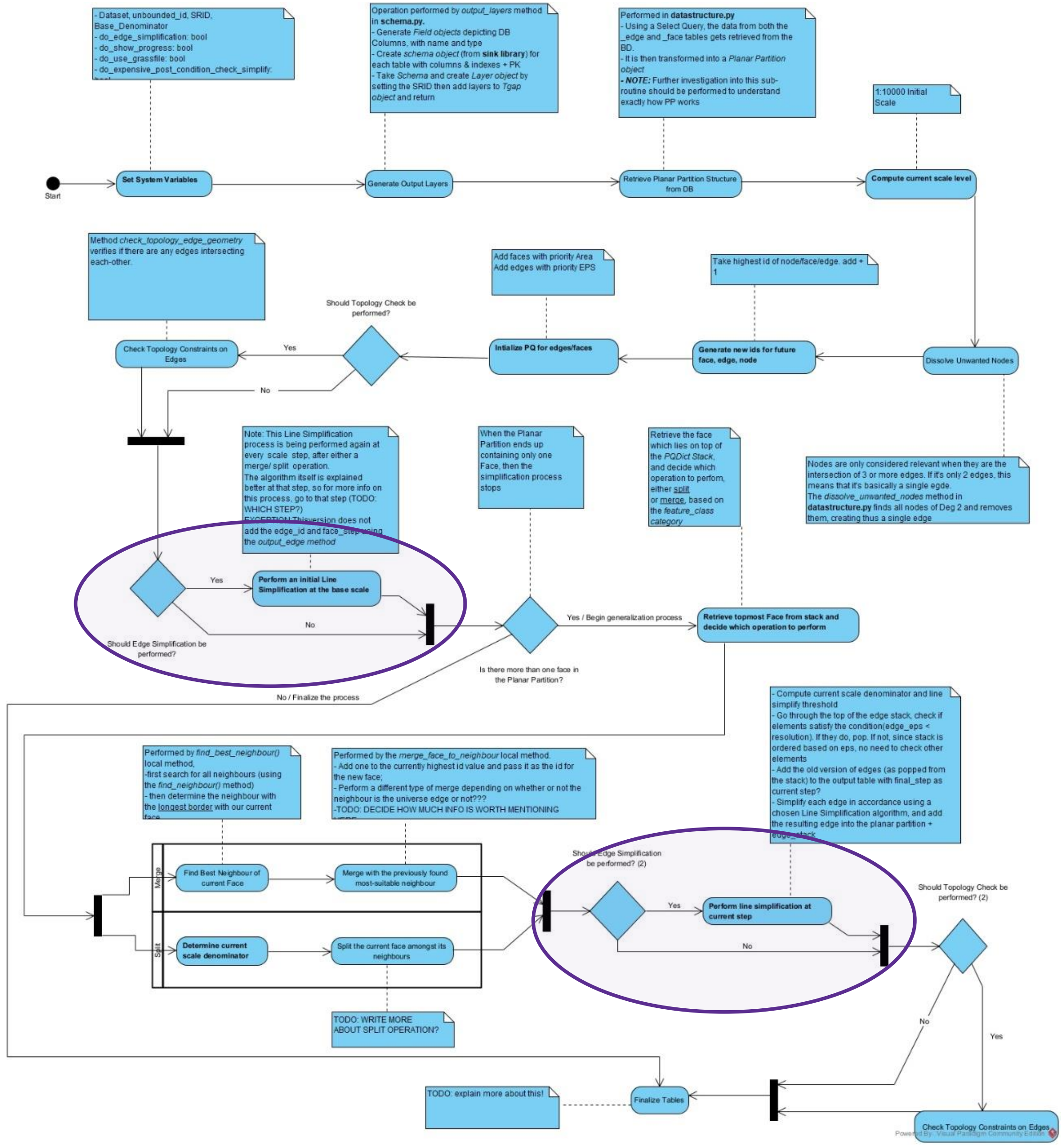


Software and Datasets

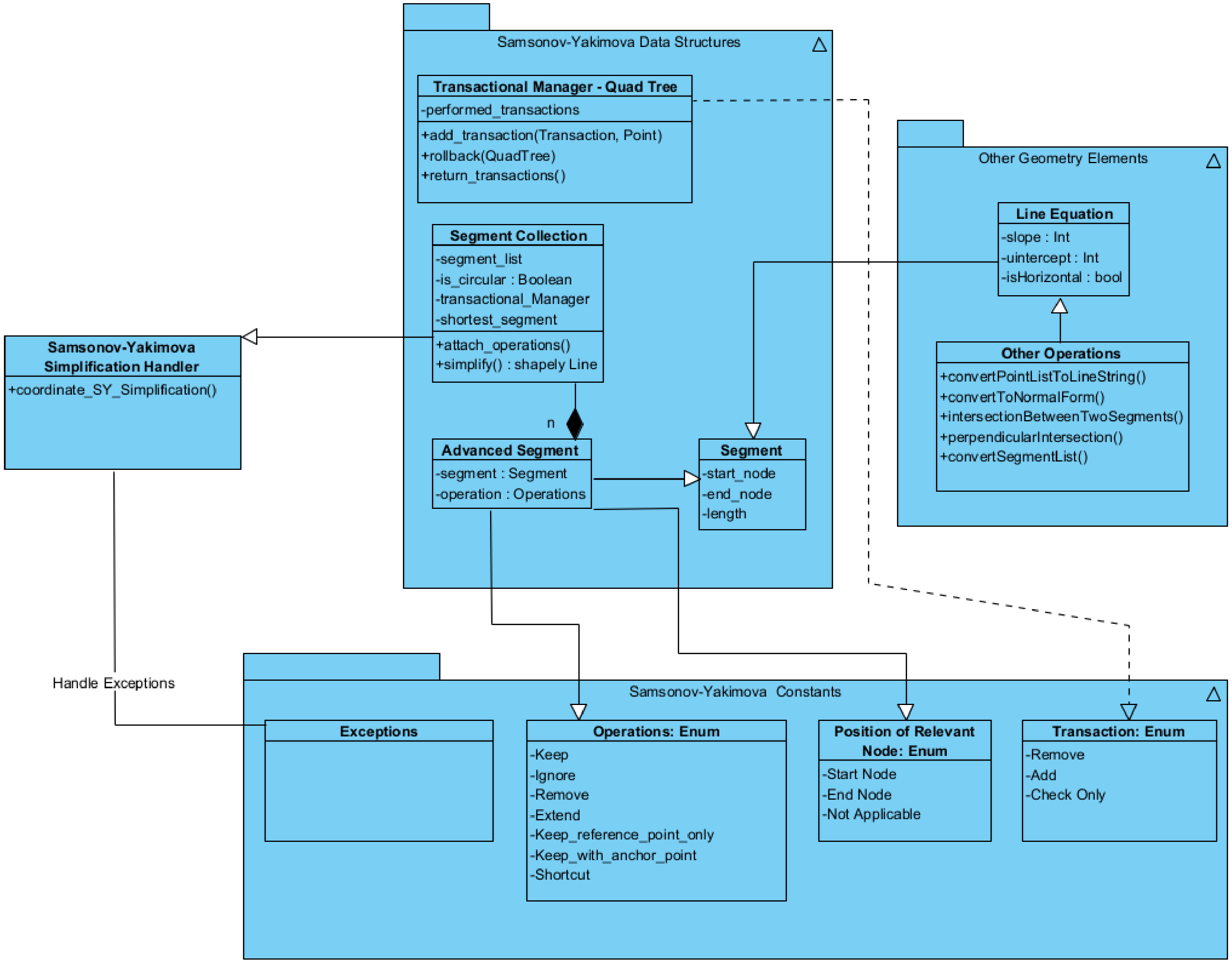


Datasets	# Faces	# Buildings	# Edges	# Points in the outline of edges
Small Dataset	98	64	187	1082
Subset-1	546	177	1173	7015
Subset-2	1585	466	3379	21484
Subset-3	4460	1594	9036	54046
Original Dataset	13238	5193	26208	158178

Original tGAP Workflow



Development of the Samsonov-Yakimova Solution



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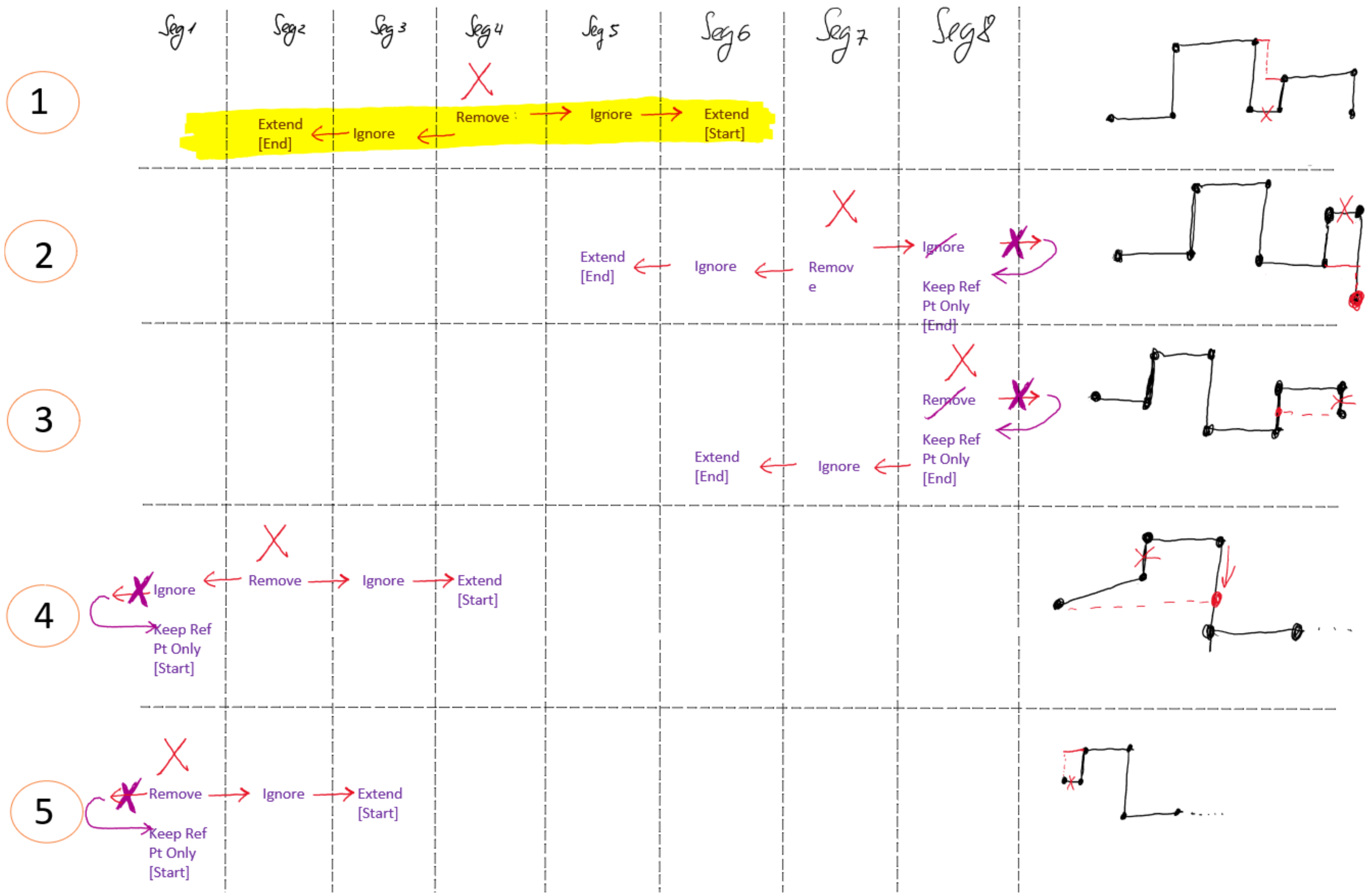
Solution Development and introduction into tGAP Software

Segment-Based Functions:
- Keep
- Remove
- Ignore
- Extend*
- Keep w/ Reference Point*
- Keep only Anchor Point*
- Short Interior

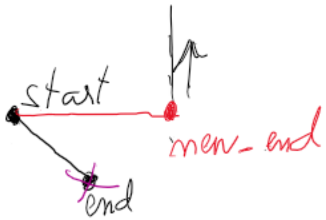


Solution Development and introduction into tGAP Software

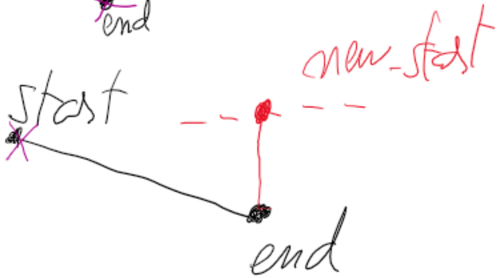
- Ignore -> don't do anything to it
- Extend Segment Start ->

- Extend Segment End ->

- Replace Segment but Keep Starting Point



- Replace Segment but Keep End Point



- Keep Segment but Consider Start as Reference Point

- Keep Segment but Consider End as Ref. Point
- Remove completely

To keep in mind when integrating into the broader tGAP System:

- Attach each topographic class a particular algorithm; order in a Priority queue which classes are more important than others
- Keep track of inter-dependencies between different algorithm
- Conversion between different Data Structures

Effect of Line Generalization in the tGAP Workflow

Datasets	# Faces	# Buildings	# Edges	# Points in the outline of edges
Small Dataset	98	64	187	1082
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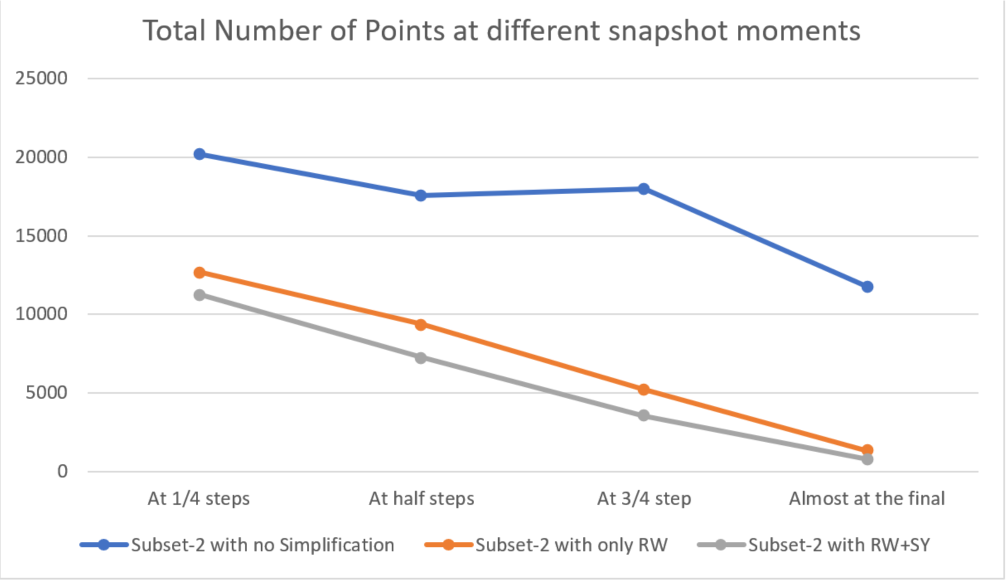
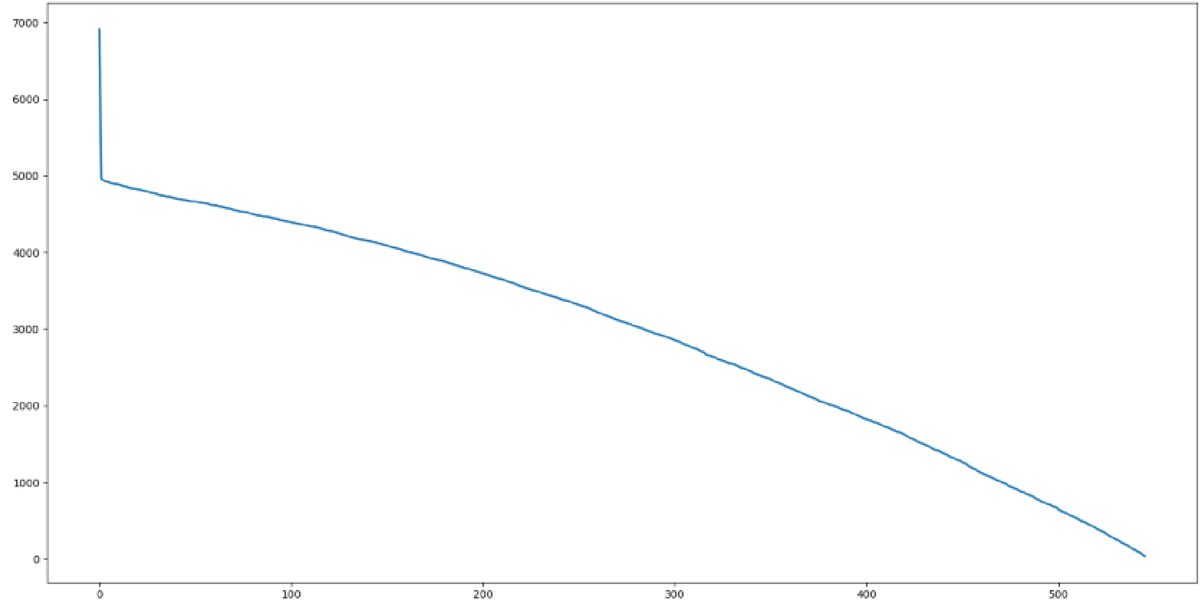
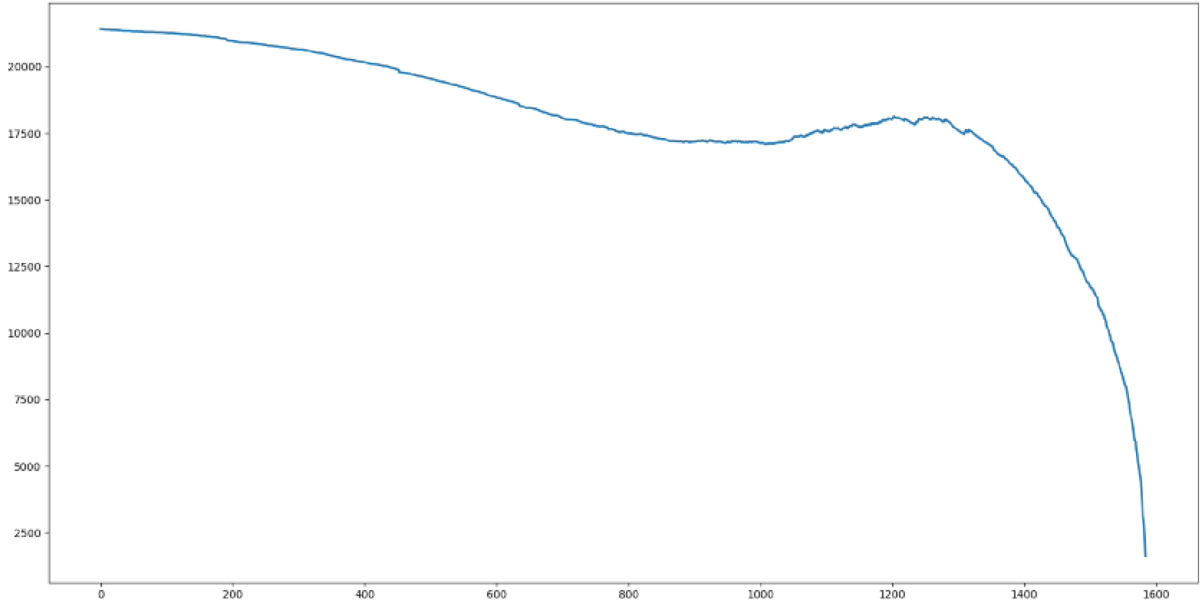
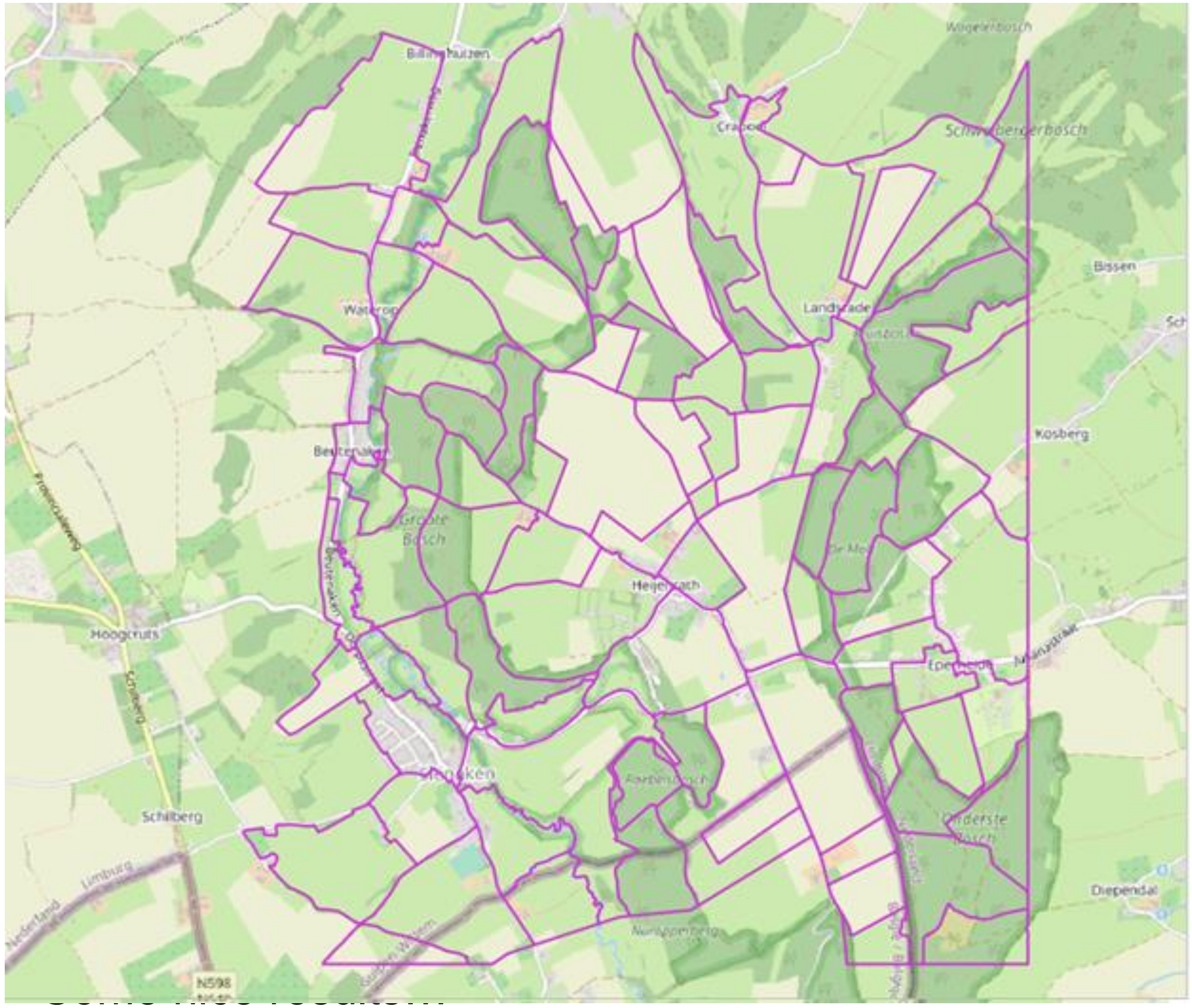
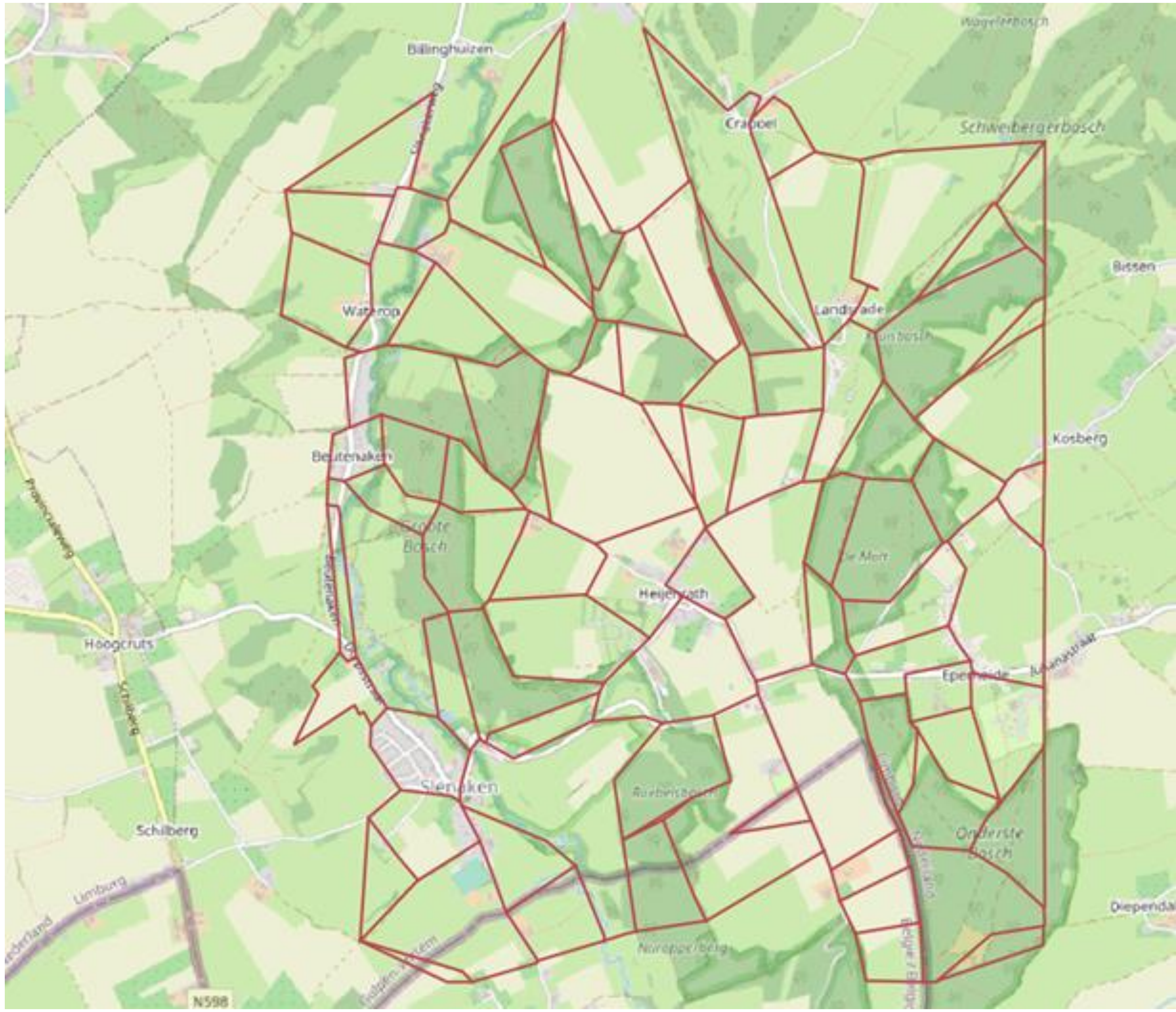






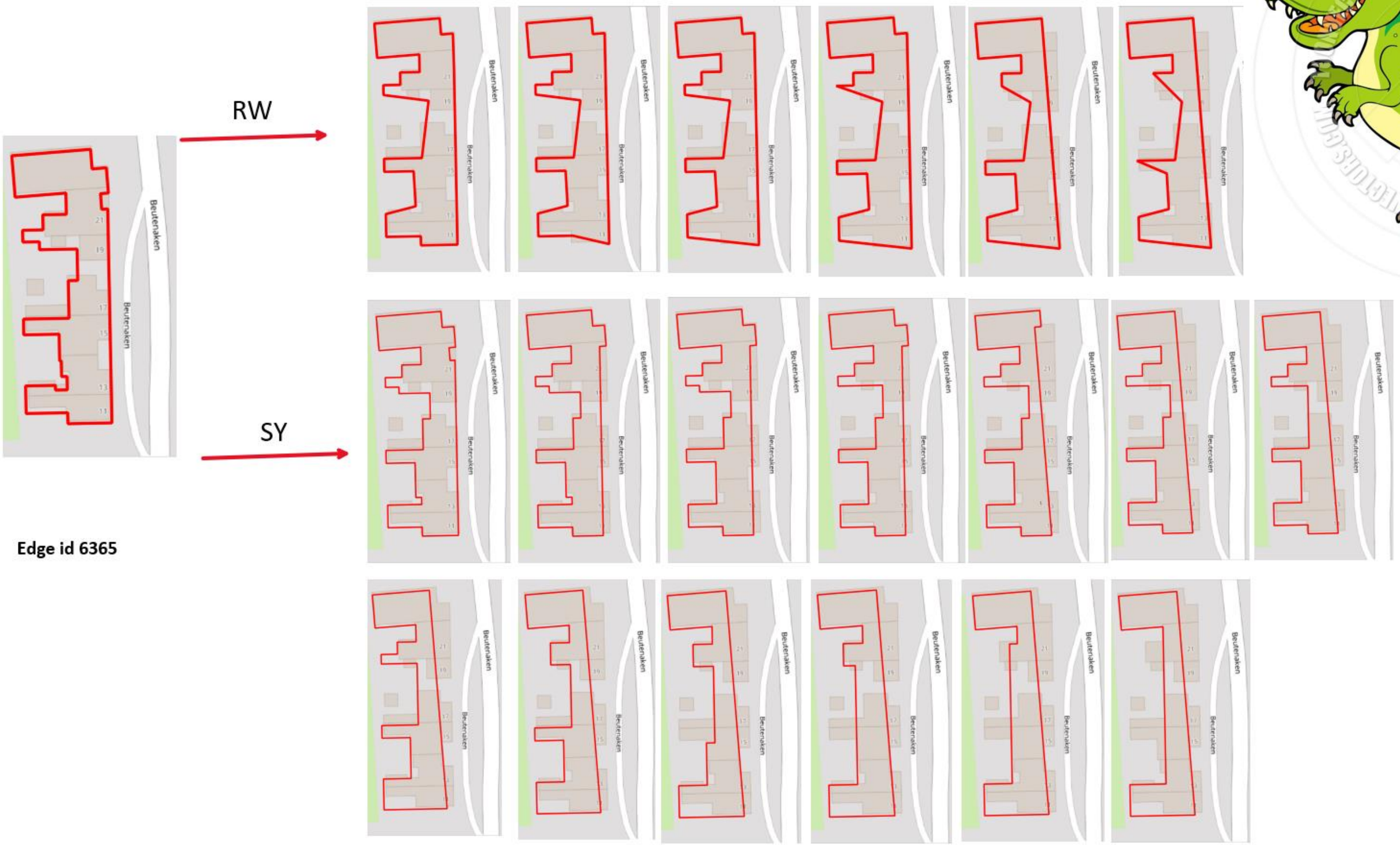
Visual Comparison – Big picture





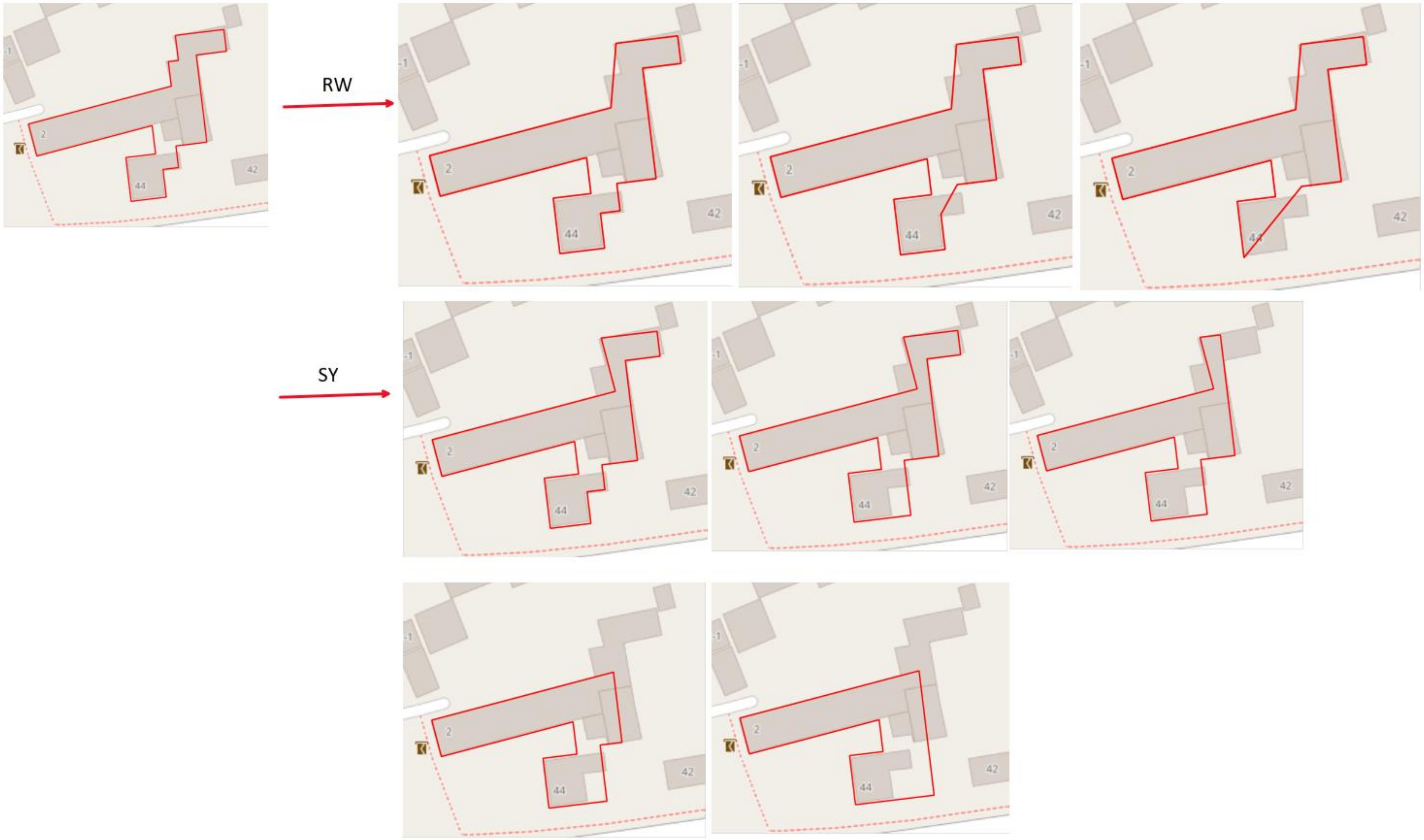
Visual Comparison – Big picture

Visual Comparison – Zoom-in



Some nice results…

Visual Comparison – Zoom-in



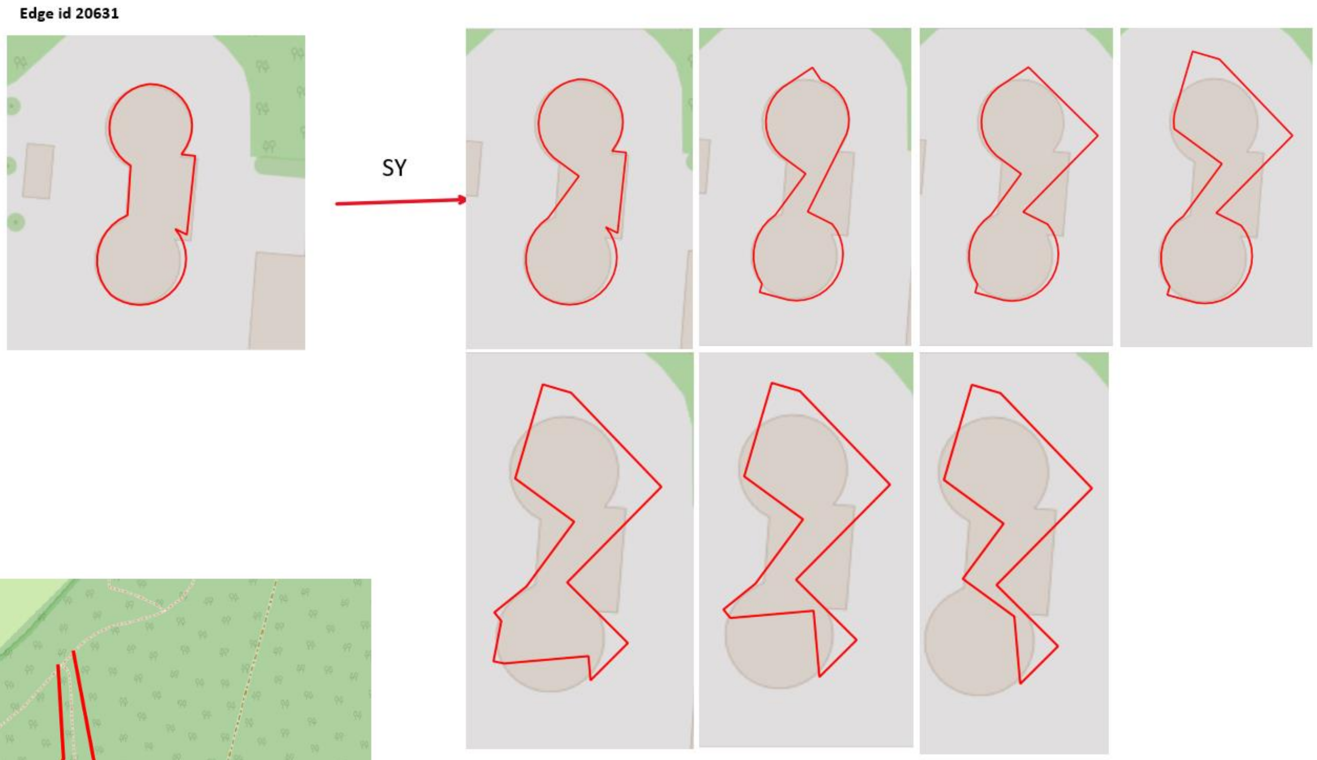
Other nice results…

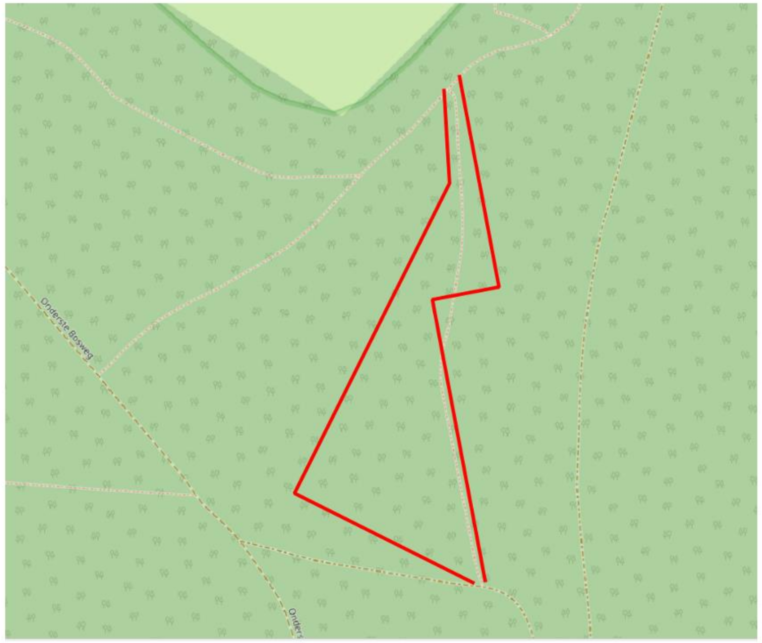
Visual Comparison – Zoom-in

One other nice results…

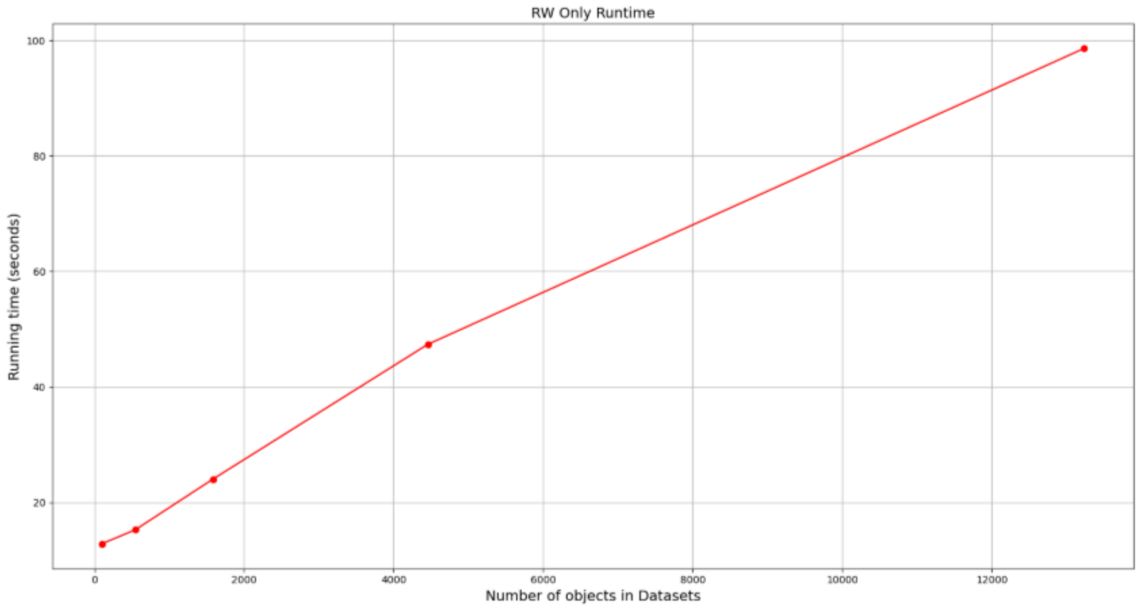
Visual Comparison

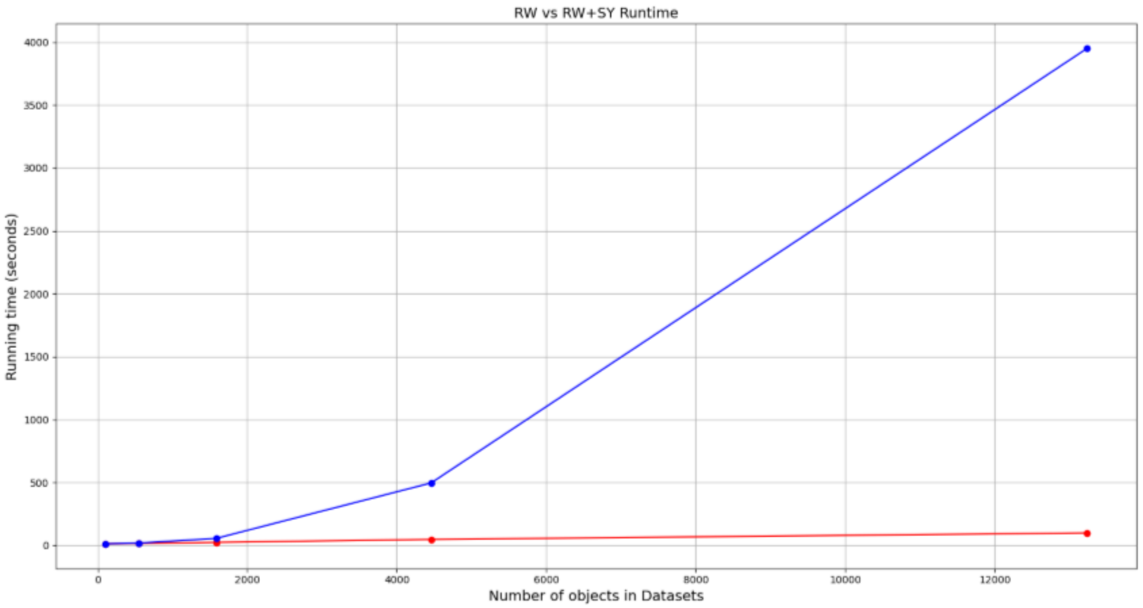
… But not all the time!



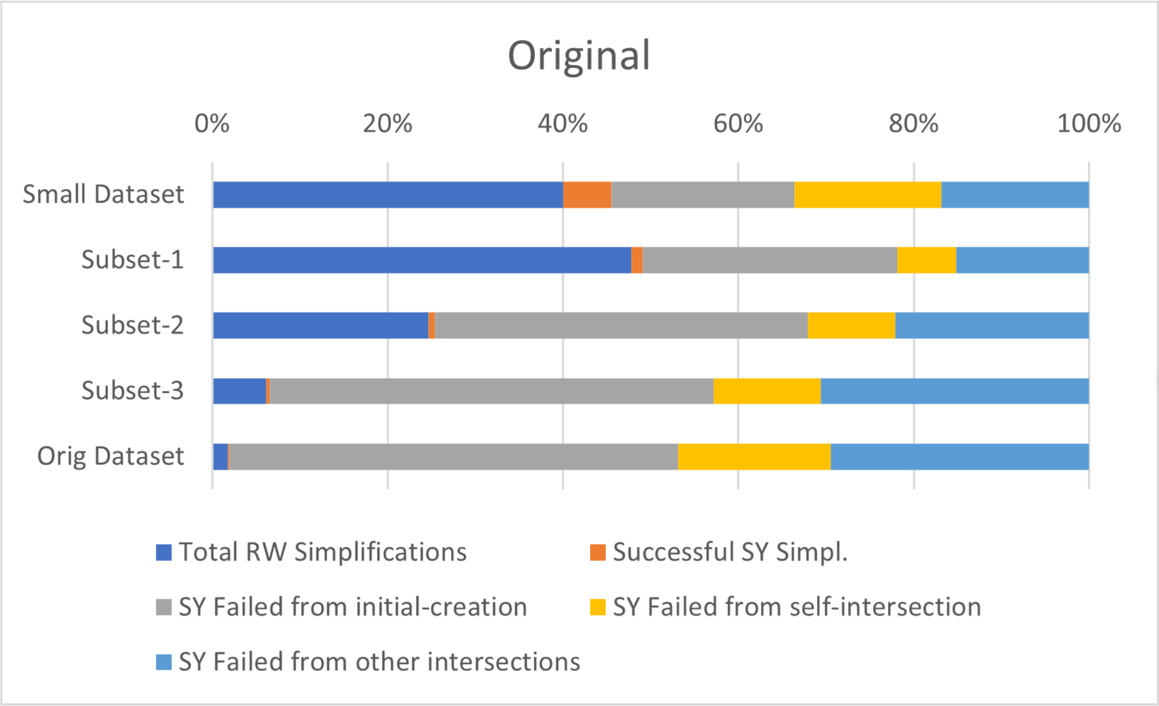


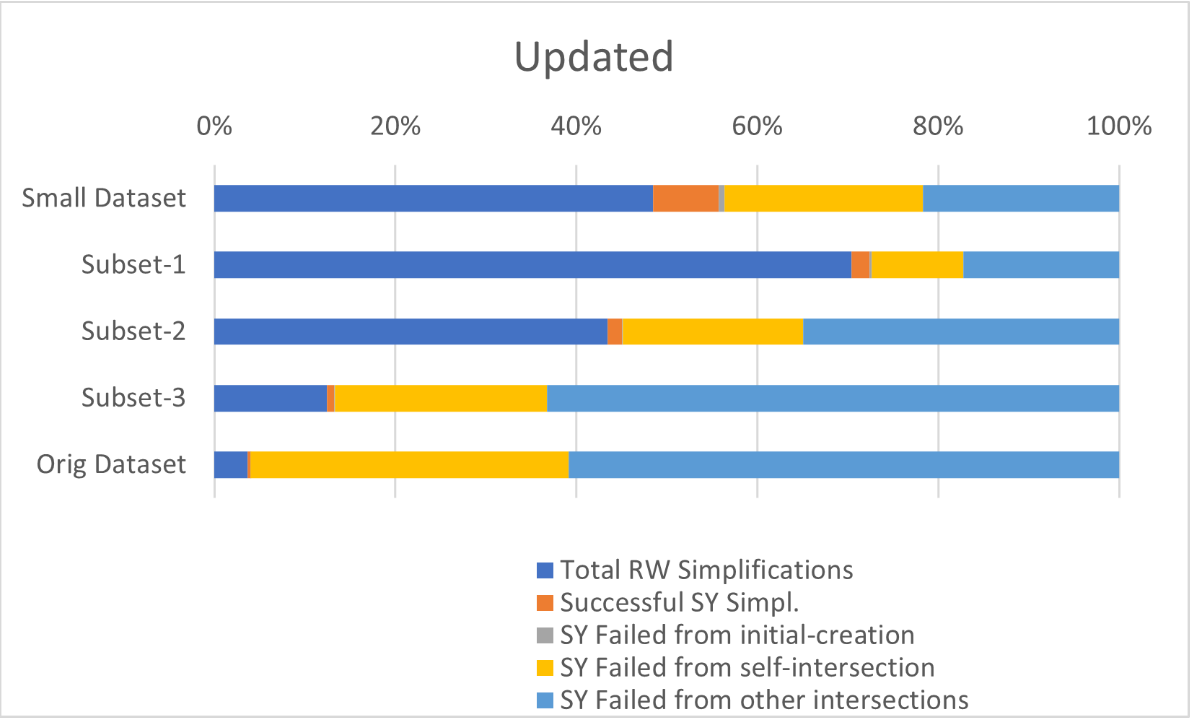
Impact on Performance



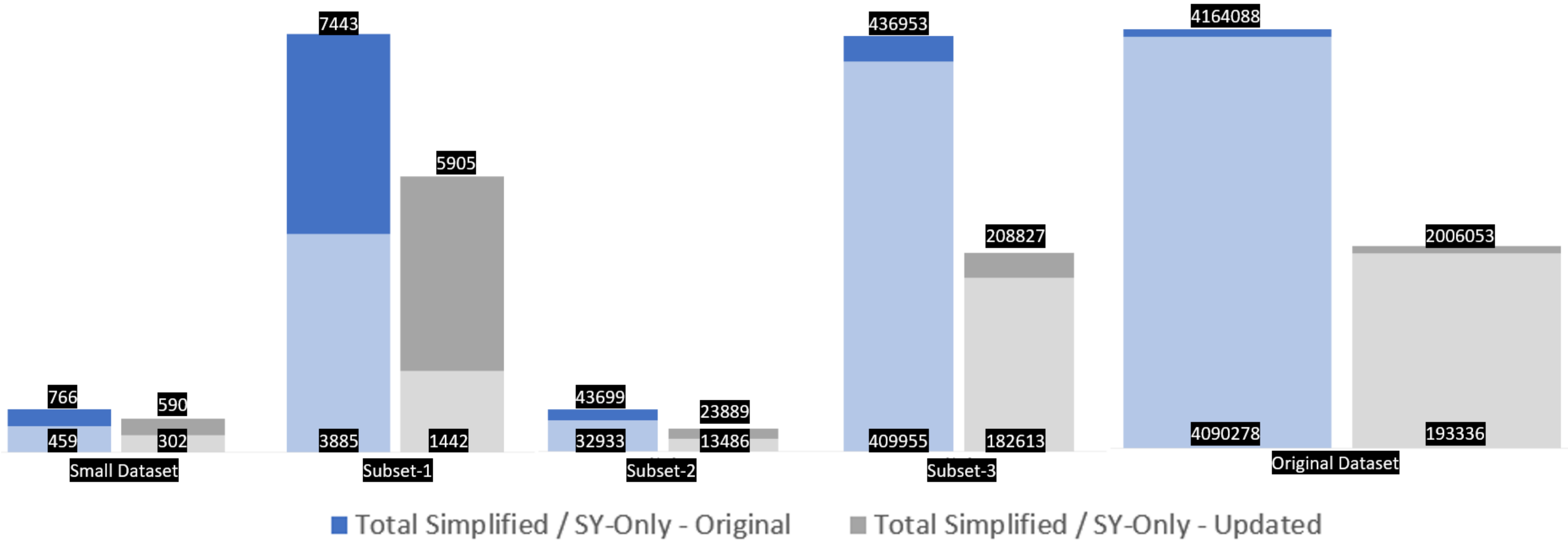


Impact on Performance

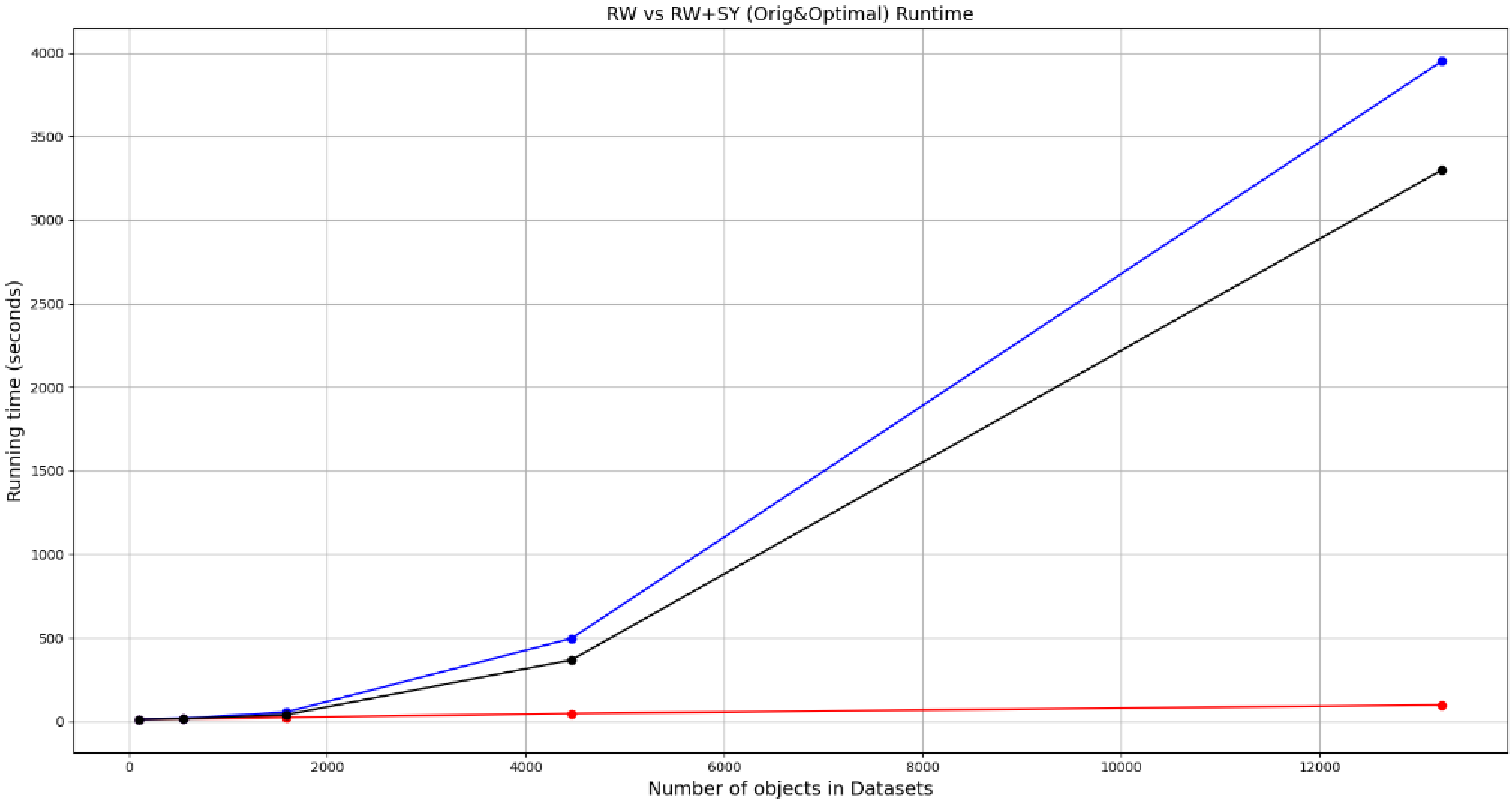




Impact on Performance – Number of operations



Impact on Performance



Conclusions

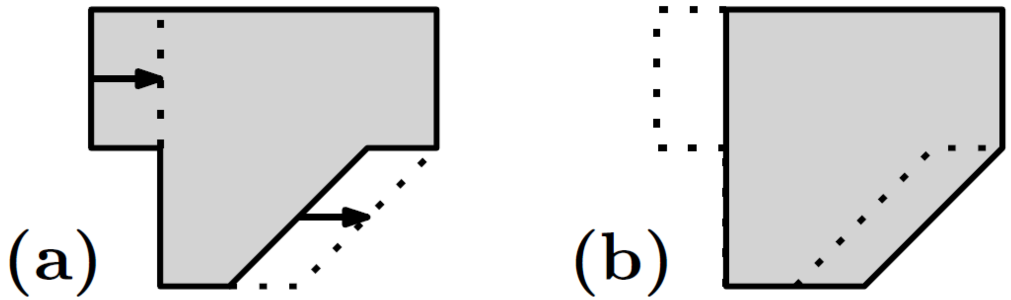
- Really promising result, with a considerable visual improvement on the end-map.
- “Best of all world” attitude, as there is no silver bullet generalization solution, adapt and adjust on a case-by-case approach
- Everything works well, and produces a topologically-correct result

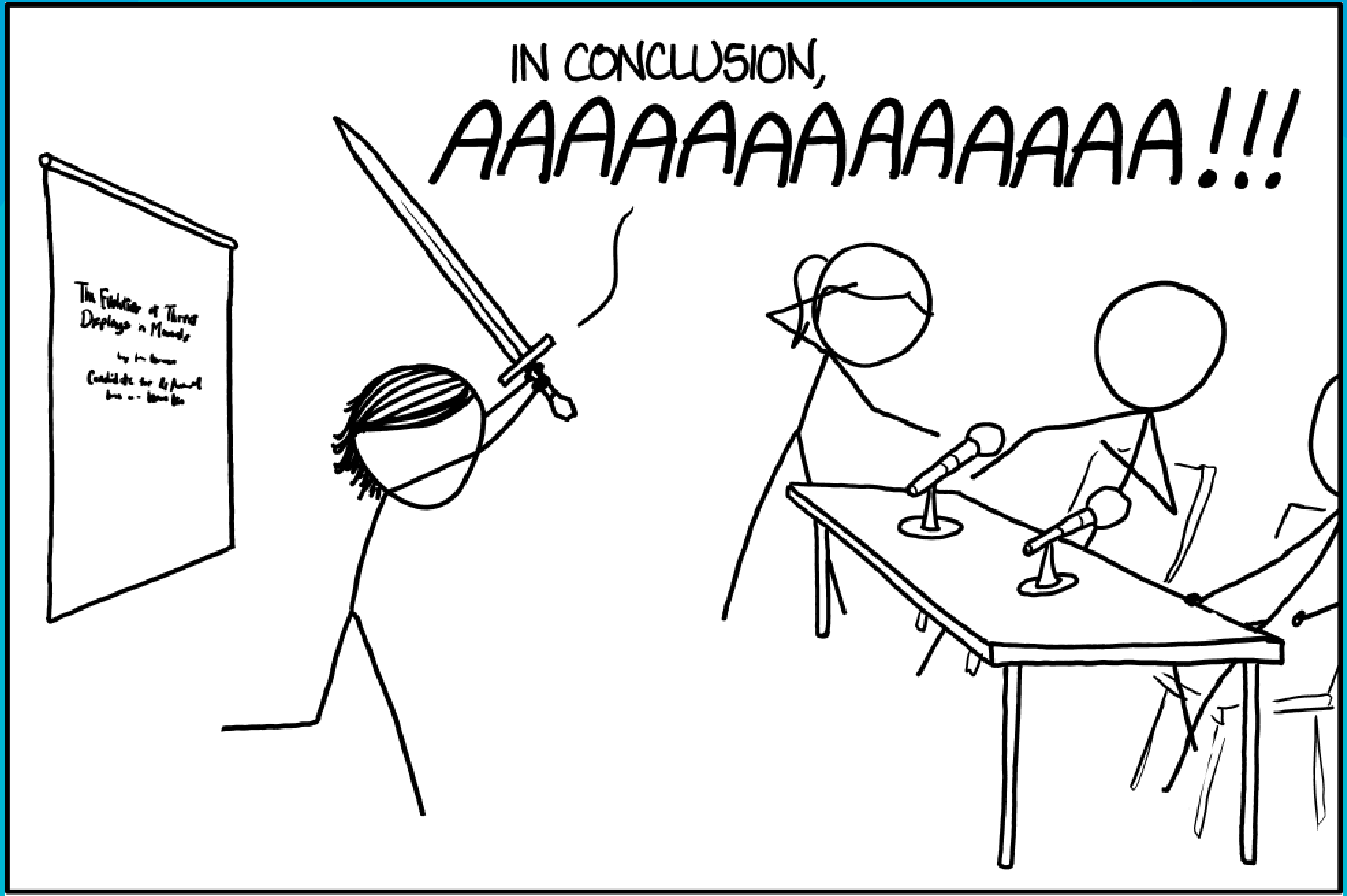
But…

- Decision of generalization should be optimized, to improve even further the result
- SY Simplification not always successful –> due to its characteristics, can become larger –> more chances to intersect with other neighbours

Future Work

- Improvement on the Selection of Edges (Angle/Geometry Comparison)
- Analyzing the impact of newly-introduced geometries (and performed changes) on the Planar Partition, and having a better bookkeeping of these changes
- Going forward with the SSC, seeing how these changes are reflected in the resulting structure, and capturing the transitions
- Change SY with a similar algorithm, with less edge-cases and situations (Edge-shift Moves algorithm)





THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.

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Q&A

Thank you!

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