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

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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?
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?
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

Intro  Theory  Methodology  Implementation  Results  Conclusion
Line Generalization in-depth concepts – Samsonov-Yakimova

Schematic
Regular
Non-Schematic
Schematic
Irregular
Sharp
Non-Schematic
Artificial
Natural
Schematic
Non-Schematic

Substitutions
Median
Diagonal
Shortcut

a) U-like
b) Z-like
c) Endpoint
d) Short

Intro Theory Methodology Implementation Results Conclusion
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
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

Implementing the Orthogonal Line
Simplification in isolation

- Adapt the original SY solution (presented by the authors), to be suitable for all the cases which may be encountered in the used Planar Partition
- Define the Mathematical Operations
- Describe the simplification scenarios (using the aforementioned Mathematical Operations)

Integrating the Simplification into the tGAP Workflow

- Define how the SY Simplification should correctly detect possible intersections with other neighbours
- Describe what criteria should the decision of which segment to be simplified be based on

Combining multiple solutions under a single algorithm

- Create the plan for deciding which simplification to use in a particular case
- Go into the changes that are required to be made to the original version of the algorithm, such that it can handle more than just one solution
- Mention possible shortfalls in the Methodology

Improving the functionality of the combined solution

- Further Discussion on the amount of data that has to be simplified

ADAPTED tGAP Generation Workflow
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

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

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

Slope: \(m = \frac{y_2 - y_1}{x_2 - x_1}\)

Y-intercept: \(b = y_1 - m \cdot x_1 = y_2 - m \cdot x_1\)

Final Line equation: \(\Rightarrow y = m \cdot x + b\)
Samsonov-Yakimova in Isolation – Focus on Types of Operations

Median

Diagonal

Shortcut

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- 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… To Compatibility Matrix
Software and Datasets

- Python
- Shapely
- QGIS
- PostgreSQL

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Software and Datasets

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<th>Datasets</th>
<th># Faces</th>
<th># Buildings</th>
<th># Edges</th>
<th># Points in the outline of edges</th>
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<td>5193</td>
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Original tGAP Workflow

Intro

Theory

Methodology

Implementation

Results

Conclusion
Development of the Samsonov-Yakimova Solution

Intro       Theory       Methodology       Implementation       Results

Conclusion
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

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Total Number of Points at different snapshot moments:

- At 1/4 steps: Orange line
- At half steps: Gray line
- At 3/4 step: Blue line
- Almost at the final: Orange line

Results

Conclusion
Visual Comparison – Big picture

Some nice results…
Visual Comparison – Big picture

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Some nice results…
Other nice results…
Visual Comparison – Zoom-in

One other nice results…
Visual Comparison

… But not all the time!
Impact on Performance

Result Analysis

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Impact on Performance

**Results**
Impact on Performance

Results
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)
IN CONCLUSION, 

AAAAAAAAAAAAAAAA!!!

THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.
Thank you!