Parallel step assignment for continuous generalization constrained with target map.

Konrad Jarocki

Faculty of Architecture and the Built Environment,
MSc Geomatics,

Delft University of Technology

July 10, 2020

Introduction

Maps – from viewing to interaction

Traditional map

Drawn on paper, in a given scale – time consuming and expensive process.

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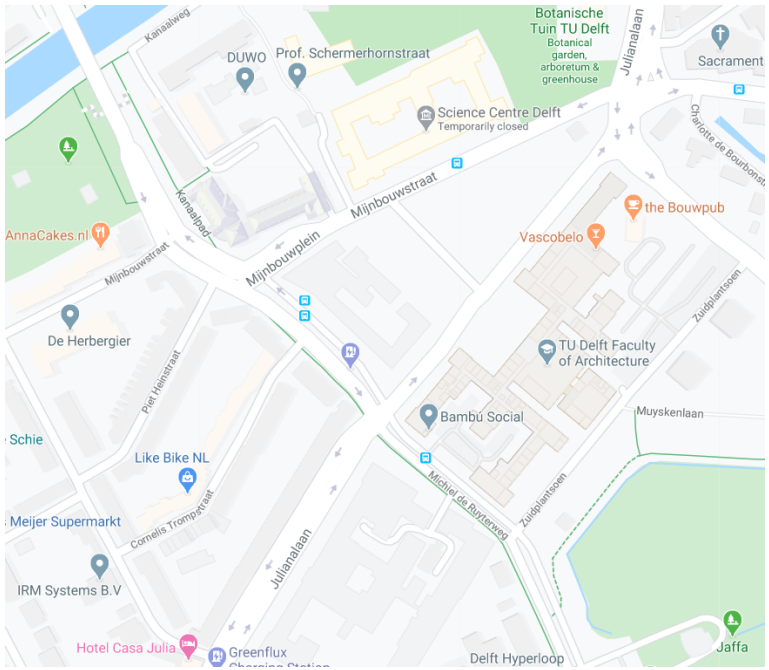

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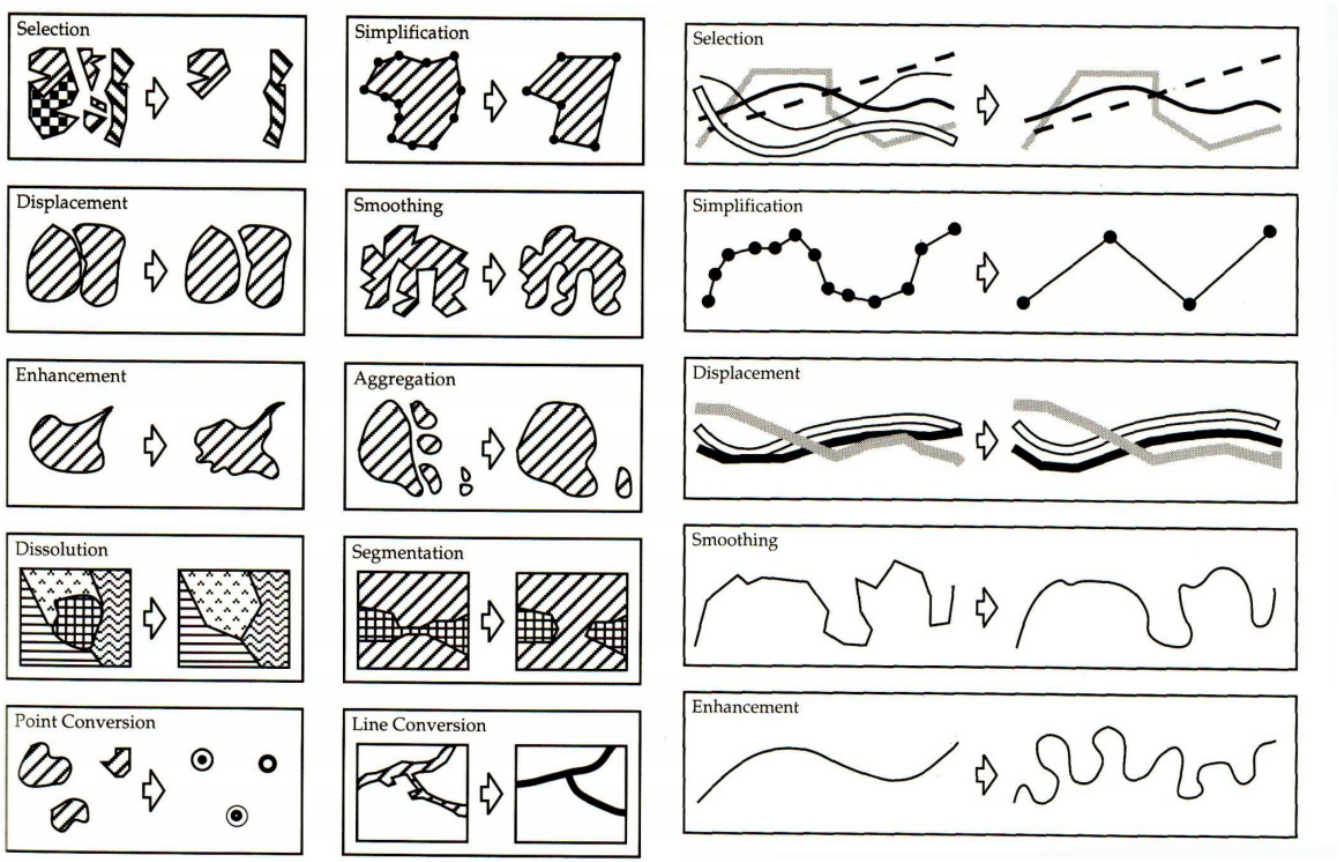

Figure: Examples of different generalization approaches.

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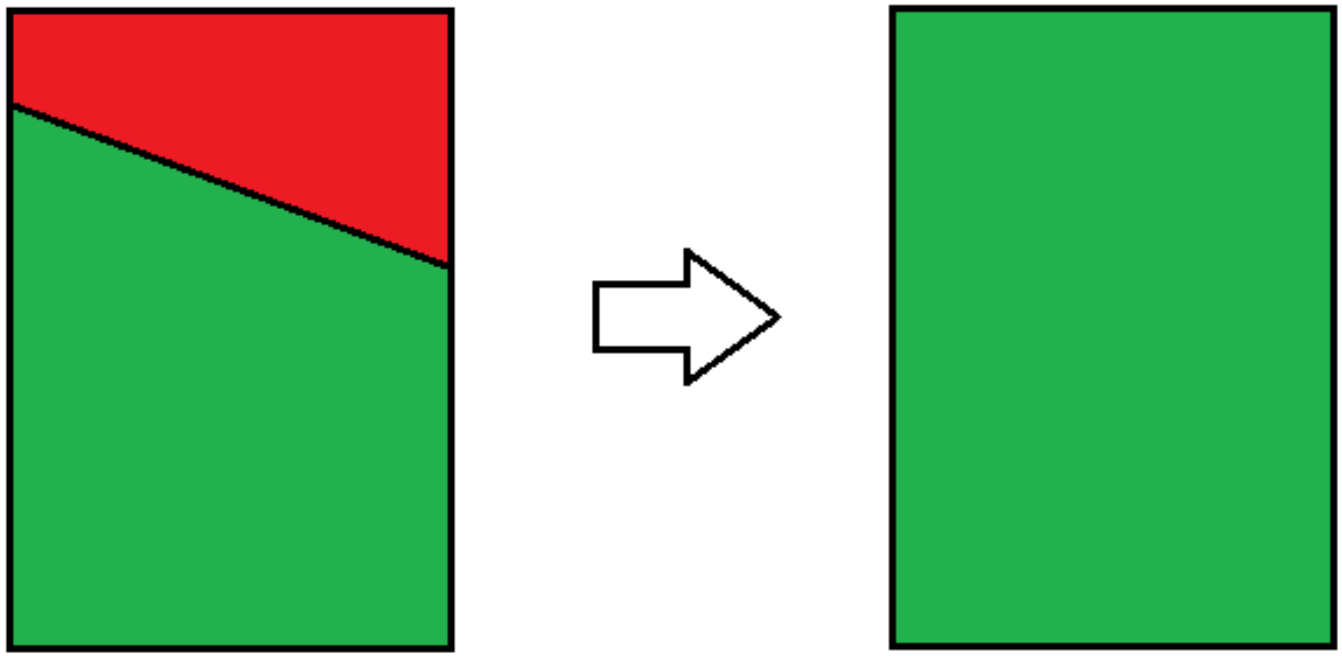

Figure: Example of a merge. One object was merged with another object to create a new one representing them both with the same class as a bigger polygon from the initial pair.

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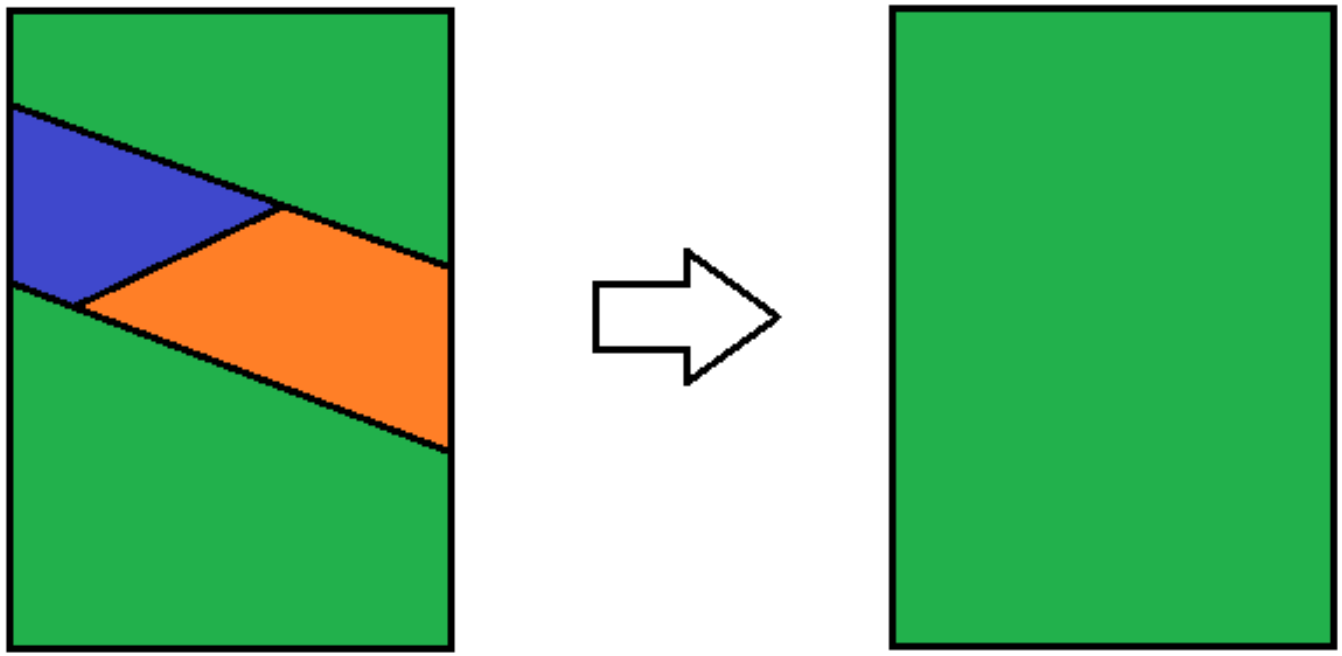

Figure: Multiple changes can involve one representation feature in the procedure which leads to **shock changes** [Peng, 2019].

Motivation

Visualization of continuous and smooth map generalization

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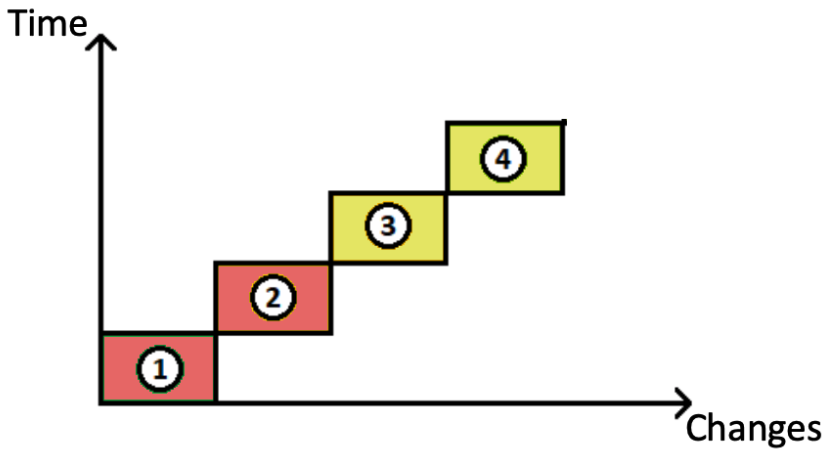

Figure: Principles of the idea. The changes are introduced one by one to make it possible to show them to the user. Each rectangle denotes one change.

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A big number of changes to be displayed leaves little time to display each of them – the problem with shock changes is solved but the interaction is still not optimal.

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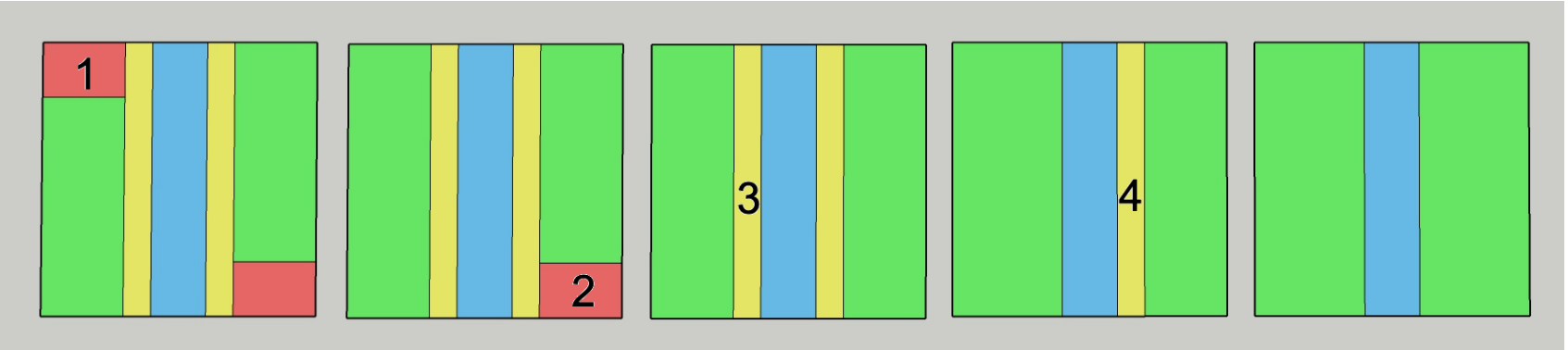
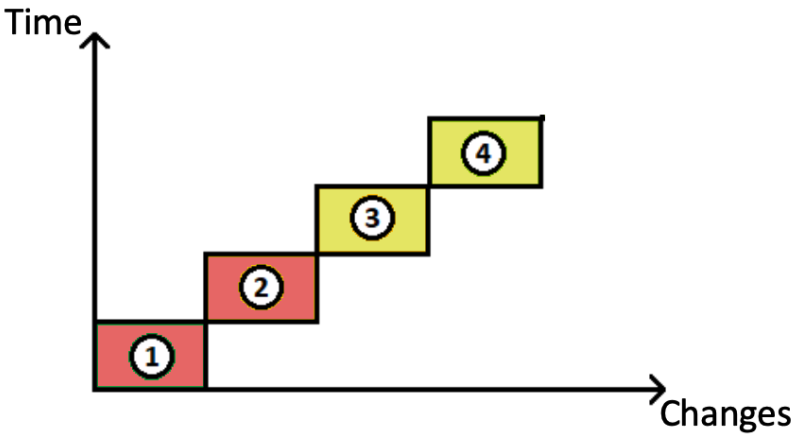
Next idea – middle ground solution!

Grouping the changes while taking into consideration the problem with shock changes and visualizing them together.

Motivation

Principles of parallel step assignment





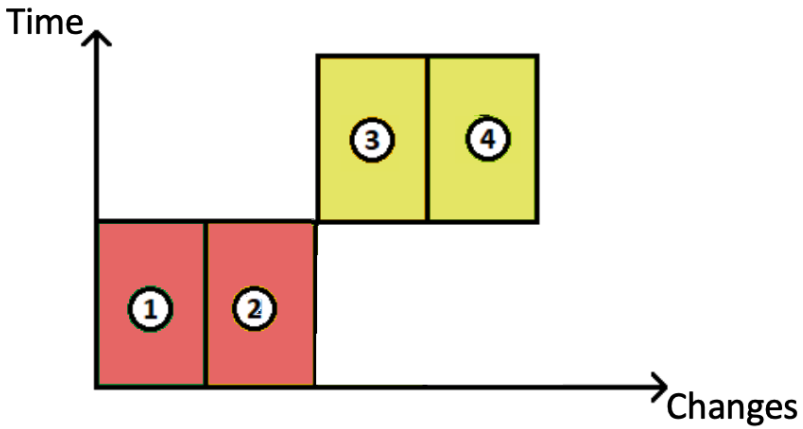


Figure: General idea behind parallel step assignment.

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and subquestions

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What are the possibilities for continuous generalization constrained with the target map by parallel step assignment and how do they perform?

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- What is the impact of the target map on accuracy? Is this solution feasible to be used in the generalization process?
- What should the display time of every step depend on?
- How to process the data for the purpose of web viewing?

Research background

tGAP

topological Generalized Area Partitioning (tGAP) – the first tree data structure for the purpose of map generalization.

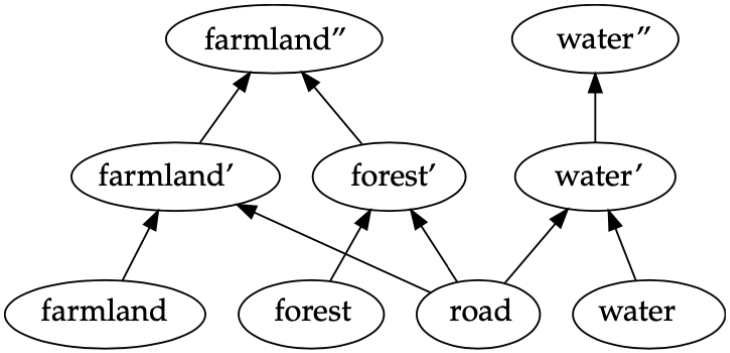

Figure: Representation of tGAP structure. Source: van Oosterom and Meijers [2013].

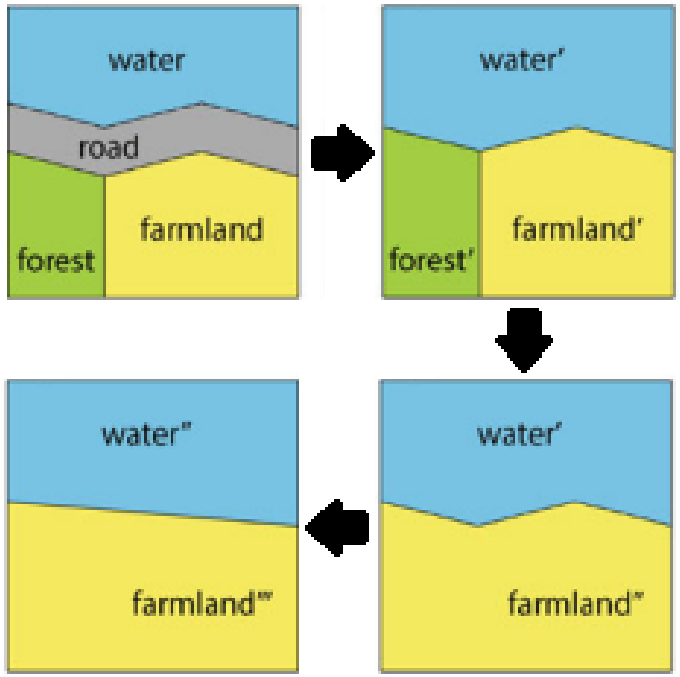

Figure: Corresponding generalization procedure visualized. Source: van Oosterom and Meijers [2013].

Research background

A* and greedy algorithms by Dr. Peng

Many ways to define the condition for generalization. Two of them are chosen for the purpose of this thesis.

- A* algorithm
- Greedy algorithm

Both developed for the purpose of Dr. Dongliang Peng's PhD thesis.

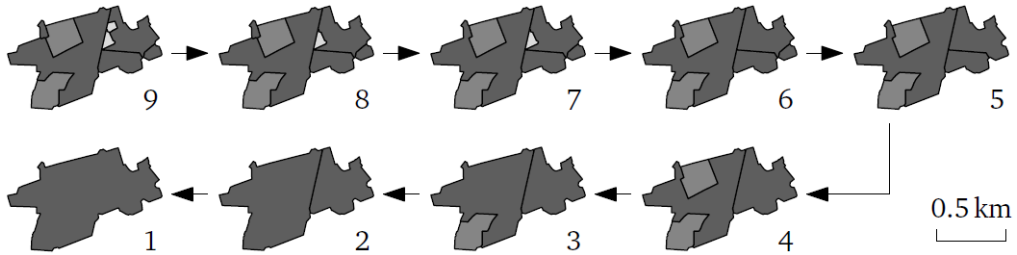

Figure: Order of changes established using one of the algorithms mentioned above. Source: Peng [2019]).

Research background

SSC and smooth solution

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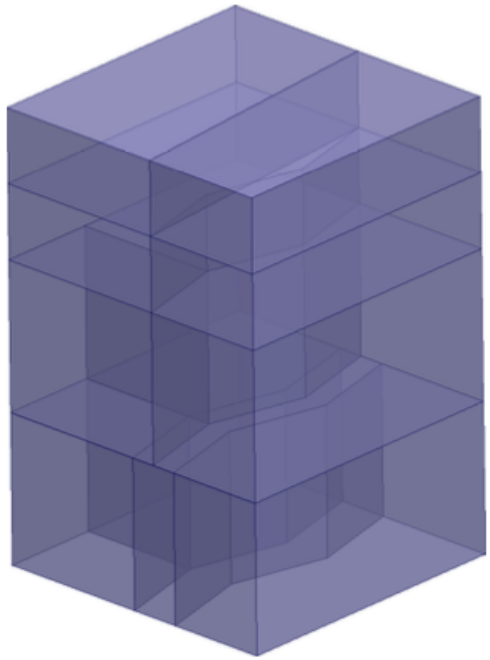

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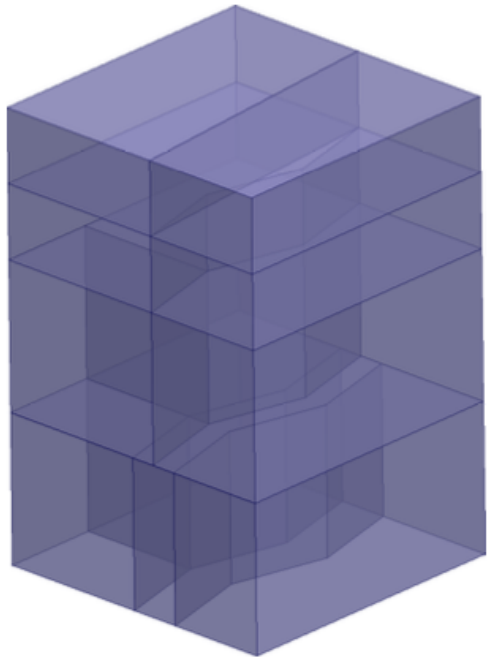

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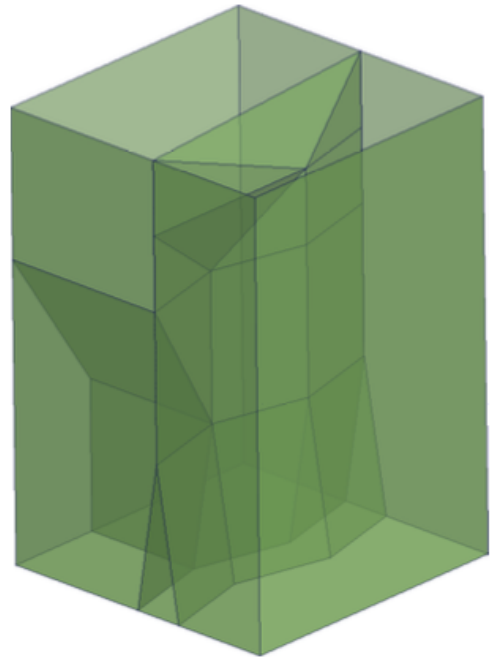
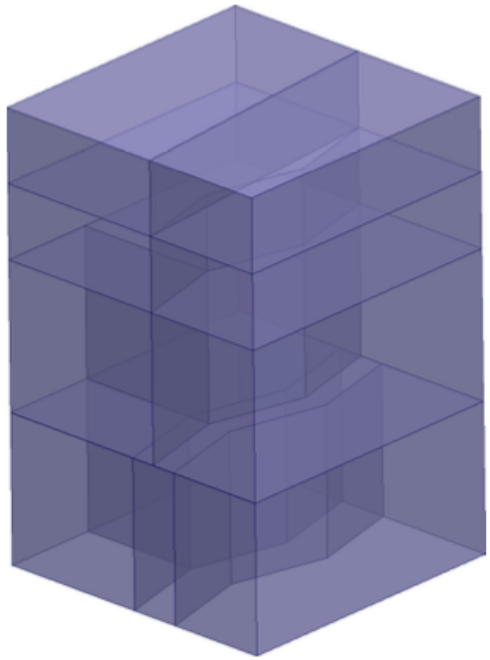


Figure: ...And its smooth version. Source: van Oosterom and Meijers [2011]

Research background

SSC and smooth solution

The map is obtained by performing **a horizontal slice** through the structure. The higher the slice, the more generalized the map (the smaller its scale).



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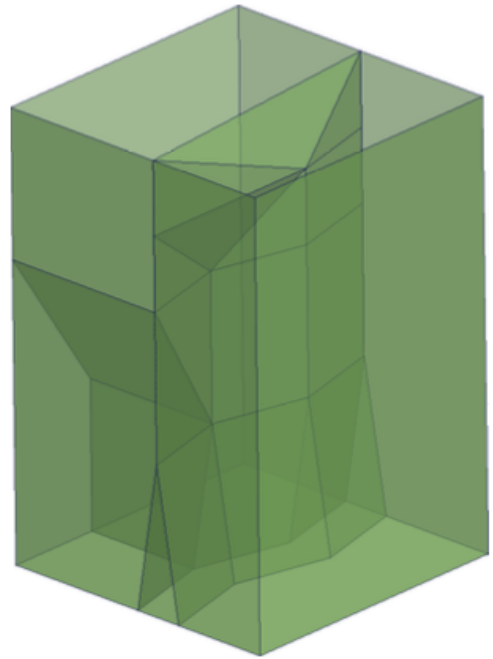

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Objectives

Three approaches

- Option A – initial map processed with a greedy algorithm (biggest neighbour) and provided target map.
- Option B – initial map processed with an A* algorithm and provided target map.
- Option C – initial map processed with a greedy algorithm (compactness) and no target map.

Objectives

General objectives

- Prepare the initial map based on a subset of TOP10NL dataset in order to meet specific requirements of A* algorithm.
- Prepare the target map based on the initial map as a required input for A* algorithm.
- Process the data in three ways (Option A, Option B and Option C).
- Implement greedy algorithms for step assignment to process results for each option.
- Assess parallel step assignment of Options A, B and C.
- Assess accuracy of the target map approaches and Option C.

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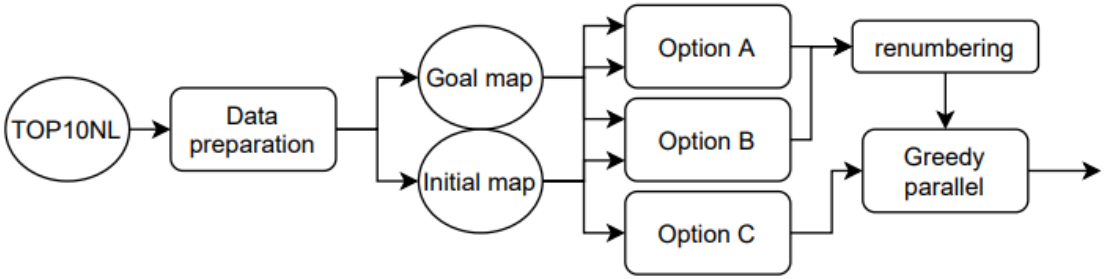
General workflow



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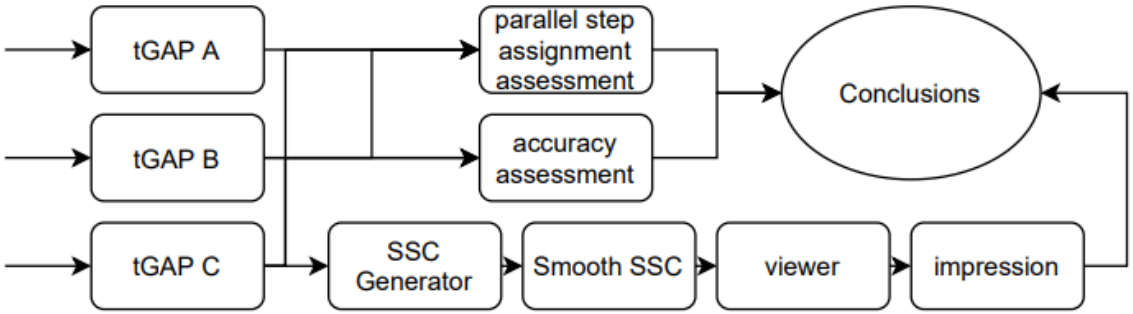

Methodology and implementation

Data preparation – initial map

One of the most important tasks was preparing the data so that it fits the requirements of used algorithms. At first, several limitations of the A-star algorithm were taken into consideration, namely:

- Simple geometries of polygons.
- Limited number of objects.
- Tolerance of spatial placement of nodes.
- Exclusion of "islands"

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Class	Before	After
Road features	3775	3770
Water features	218	65
Urban features	5211	453
Forestation	2928	2715
Farmland	1086	1086

Figure: Number of objects assigned to every type of class before and after processing.

Methodology and implementation

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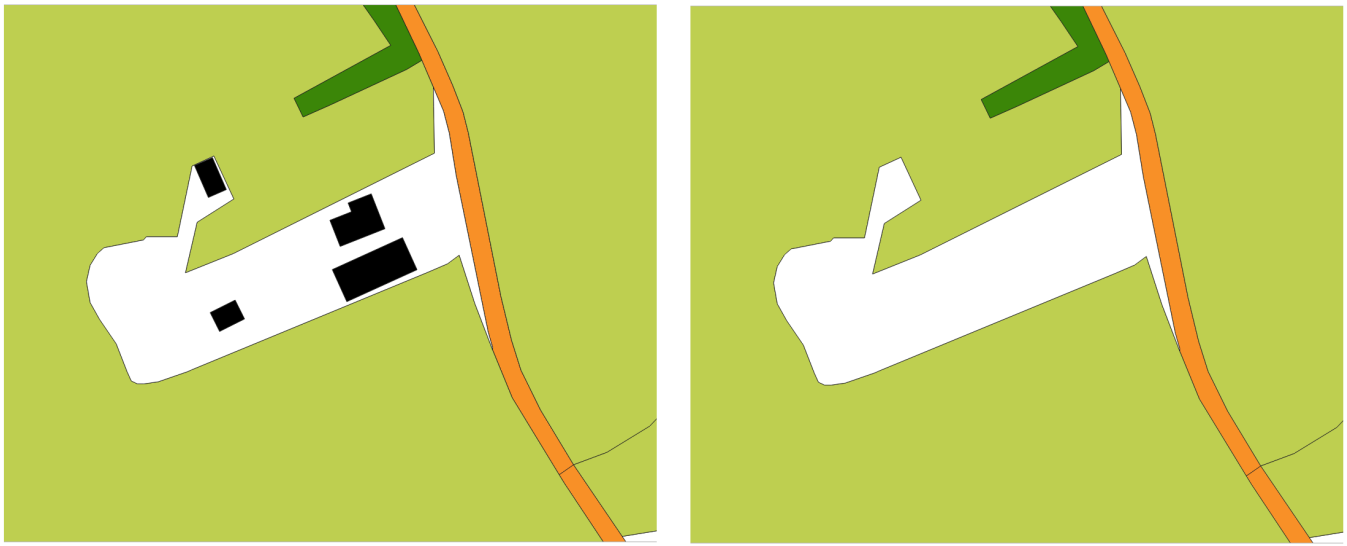

Figure: Example of data transformation in the preparation process.

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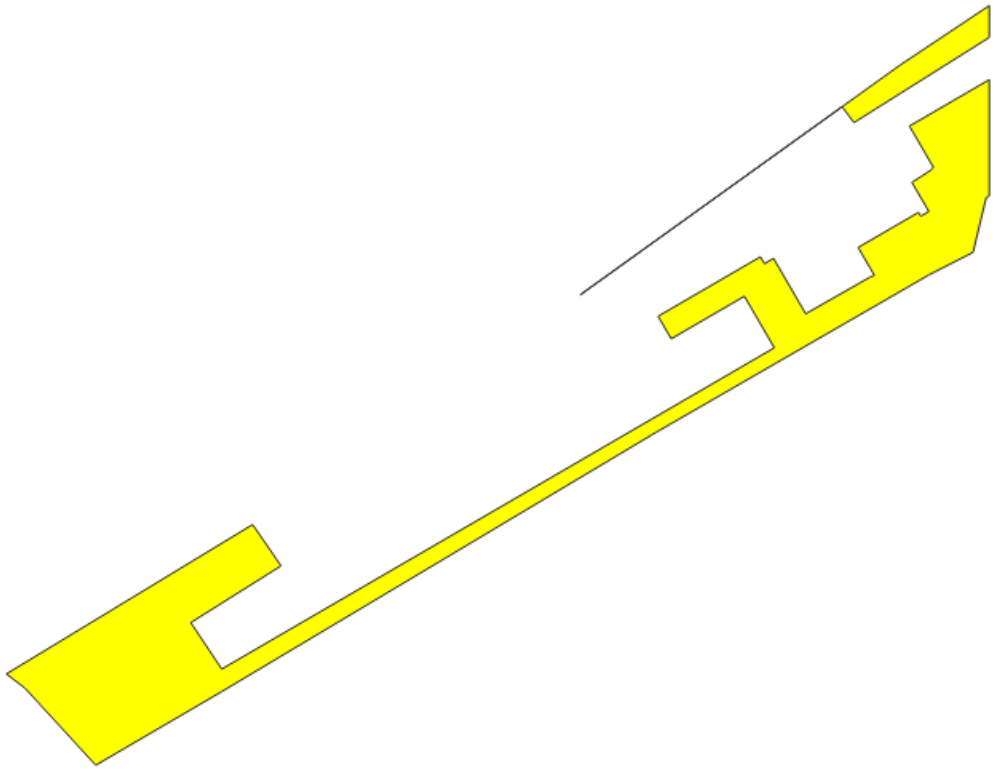

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Methodology and implementation

Data preparation – initial map

Figure: Original dataset in comparison to the initial map.

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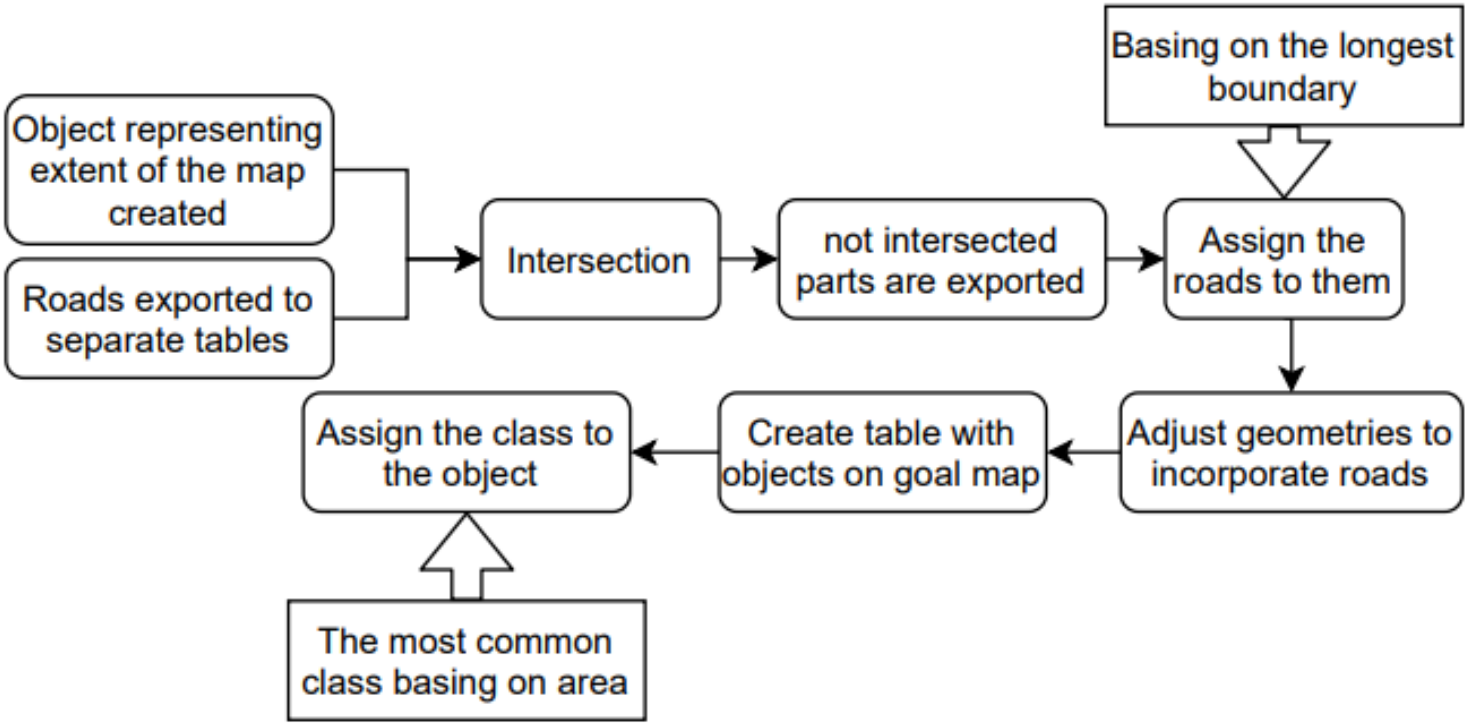

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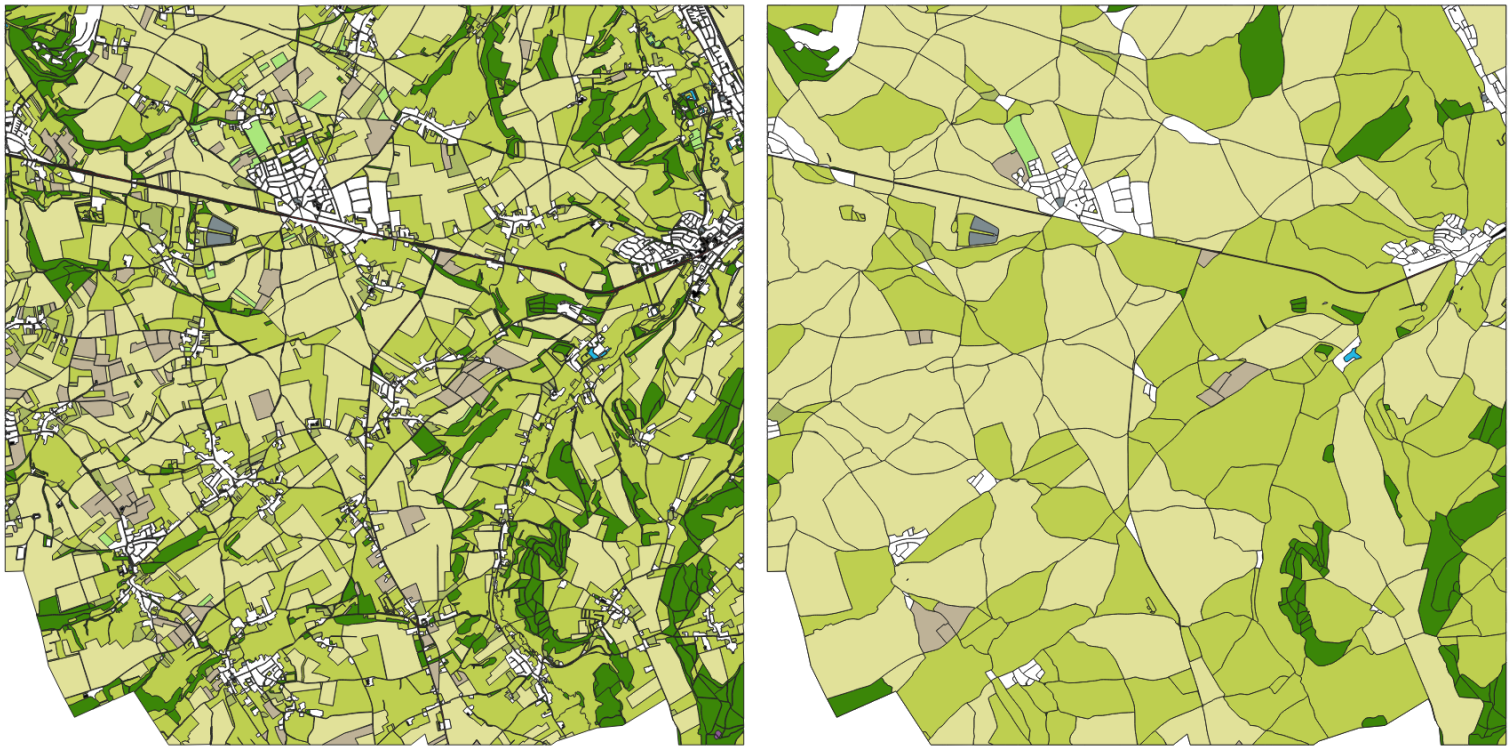

Figure: target map compared to initial map.

Methodology and implementation

Option A – GreedyGoal – generalization sequence

To make sure that the class of the final object for every sub-tree created is the same as the class of linked object on the target map, the class of a parent is adjusted based on similarity of children and linked object classes.

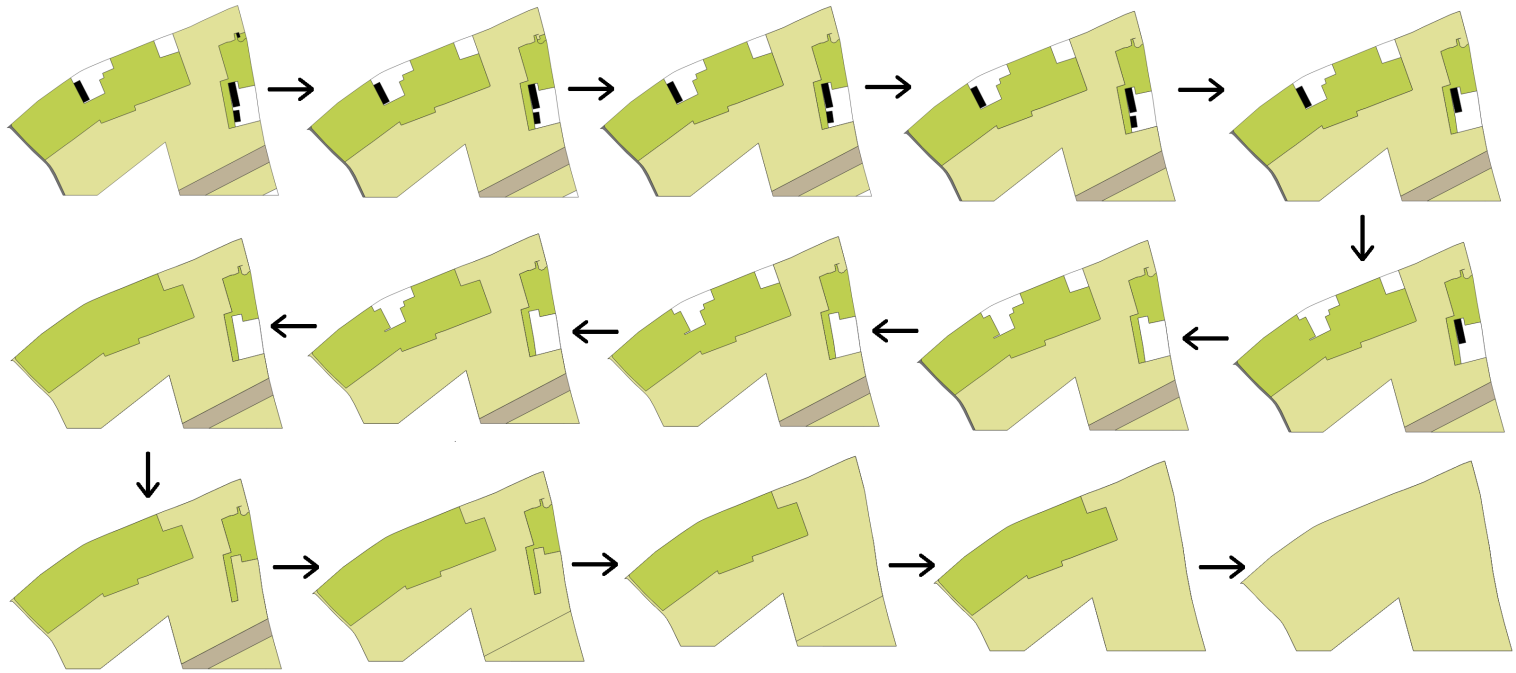

Figure: One of the sub-trees created for Option A visualized.

Methodology and implementation

Option B – AstarGoal – generalization sequence

Current state-of-the-art solution results with a CSV file containing information about the generalization sequence. This information needs to be transformed to create a geometrical representation of the map (in suitable tables).

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ID	child 1	child 2	passive	active	class	last
2414	3764	3750	3764	3750	14010	not_end
2415	1194	1205	1194	1205	14130	not_end
2416	250	214	250	214	14130	not_end
2417	735	634	735	634	14130	not_end
2418	192	210	192	210	14010	not_end
2419	2034	2695	2034	2695	14130	not_end
2420	3459	3410	3459	3410	14130	not_end
2421	3369	3342	3369	3342	14130	end
2422	1047	1116	1116	1047	14010	not_end
2423	2553	2668	2553	2668	14010	not_end
2424	2696	2678	2696	2678	14010	not_end
2425	2330	3845	2330	3845	14010	end

Figure: Structure of the file with information about the generalization sequence.

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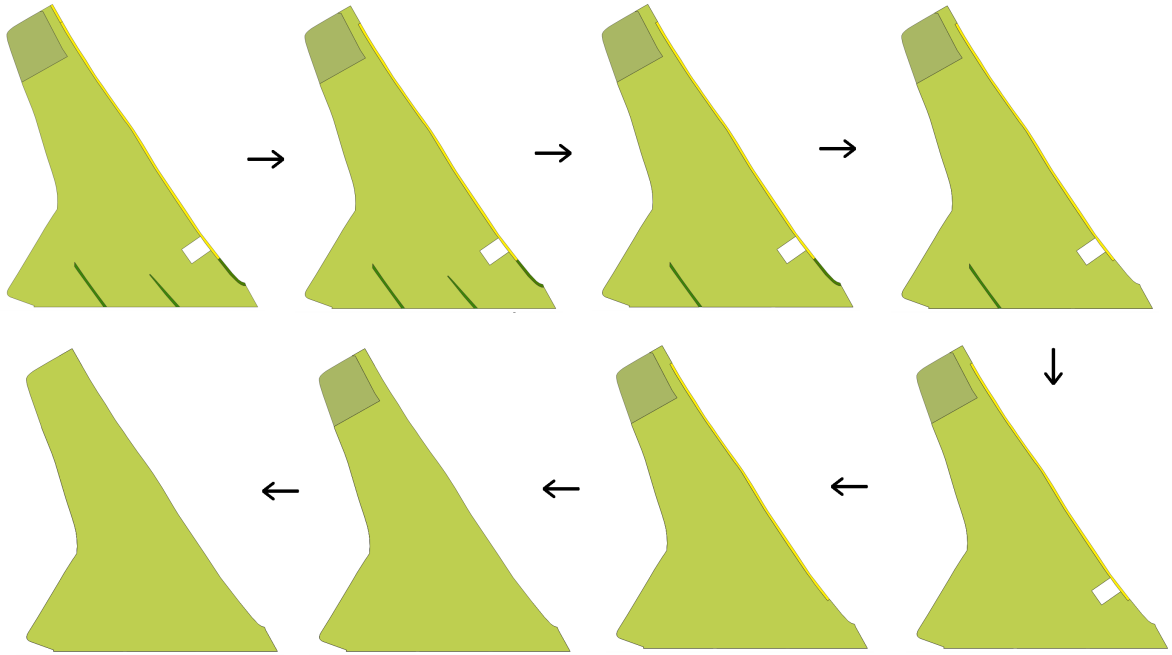

Figure: One of the sub-trees created for Option B visualized.

Methodology and implementation

Option C – GreedyNogoal – generalization sequence

For Option C no target map is provided. The algorithm will stop the generalization procedure when the same number of polygons as on the target map will be visible on the processed map (590).

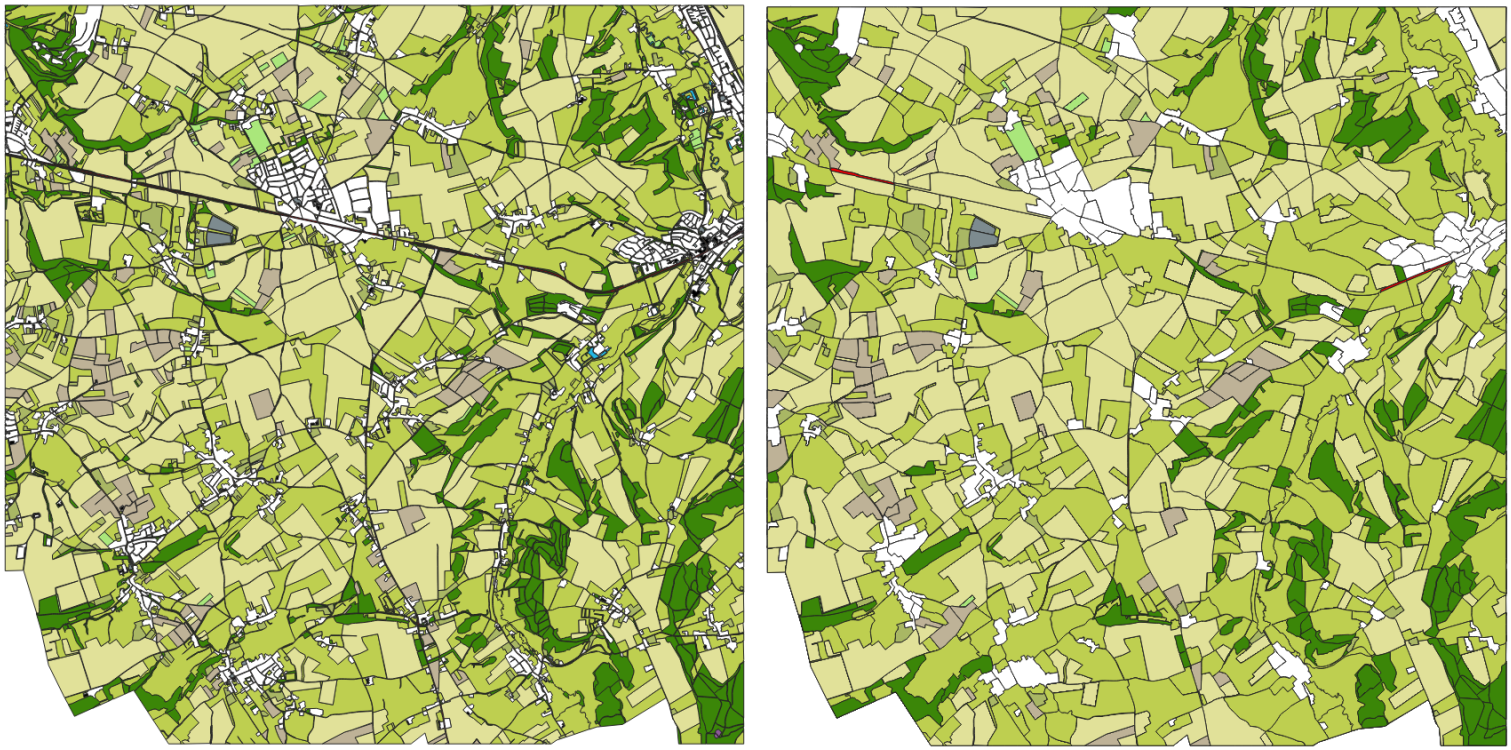

Figure: Initial map and a final map with 590 objects remaining.

Methodology and implementation

Parallel step assignment

For each option a greedy algorithm was proposed.

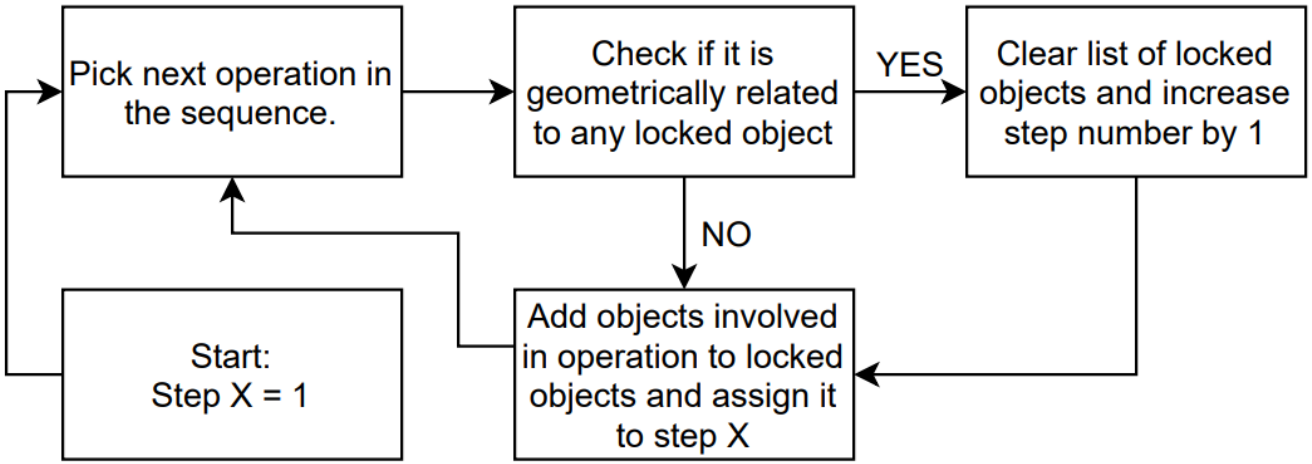

Figure: Generic diagram describing the greedy algorithm used for parallel step assignment. In Option A and Option B algorithm continues assignment for the same step for operation from another sub-trees with the same number in the sequence.

Methodology and implementation

Web viewer and SSC

With parallel steps created, the results need to be visualized to assess the experience. For that purpose, the current state-of-the-art solution will be used with adjustments for Option A and Option B.

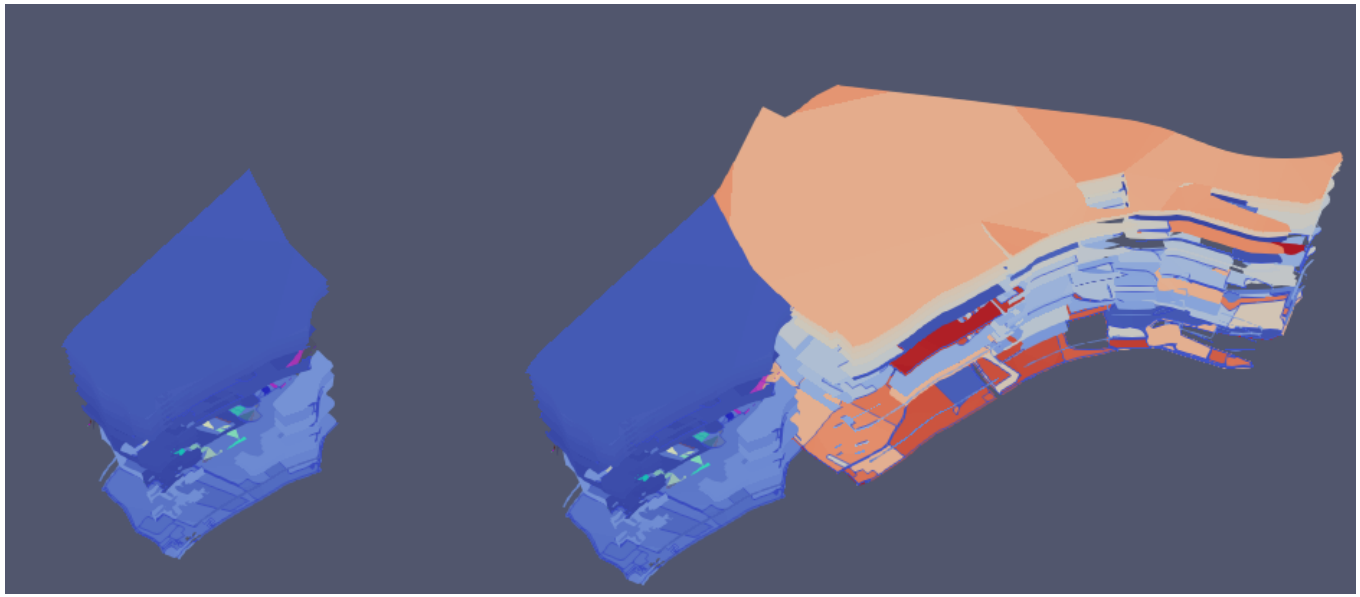

Figure: Two SSCs created for separated objects in Option A and B merged together.

Methodology and implementation

What about the parameters?

During the development of methodology it was concluded that display time should have the same weight for every step to avoid problems with consistency between two separate tiles of the map. Total number of objects area for every step is considered as a more suitable parameter than the number of objects. Several values described as percentage of total area were tested in a web viewer to find the value making the smooth transition visible while not overwhelming the user with the number of changes shown at the same time.

Methodology and implementation

Assessment – parallel step assignment

First part: variance and variance-mean-ratio (VMR) of total area of objects assigned to specific steps for every option.

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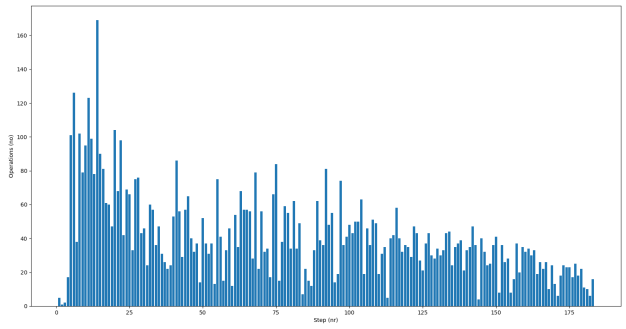

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Scale	Objects [%]	Operations
1:15000	44.4	2207
1:20000	25	4781
1:25000	16	5972
1:30000	11.1	6620
1:35000	8.16	7010

Figure: Chosen scales of map with numbers of objects with respect to the initial map.

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Impact on parallel step assignment is a crucial part of the research, but the general utility for map generalization needs to be assessed.

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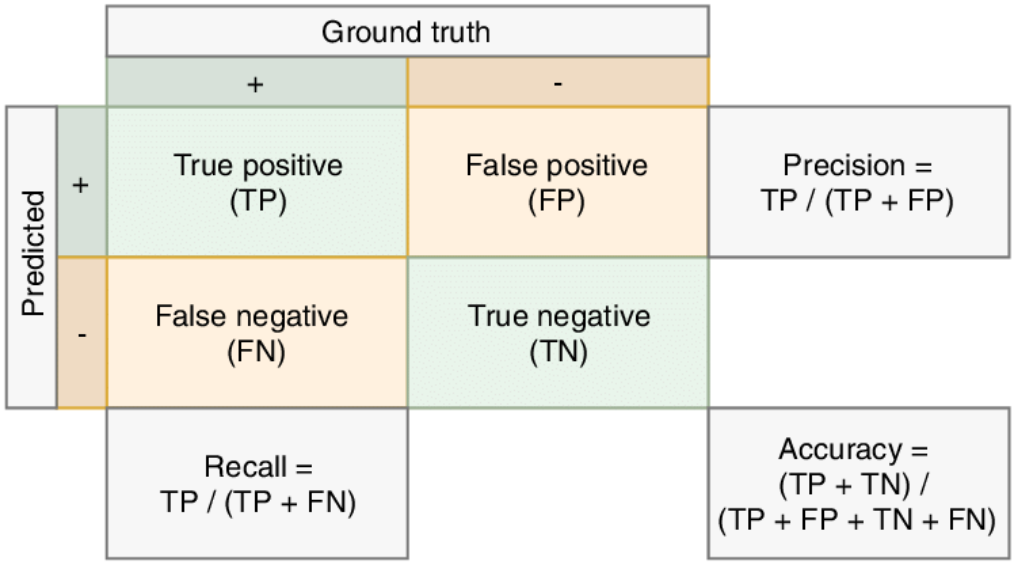

Figure: General idea behind the confusion matrix.

Results

First impression in a web viewer and parameterization

Several options were tested – 1%, 5% and 10% of the total area.

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Results

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Results

Option A

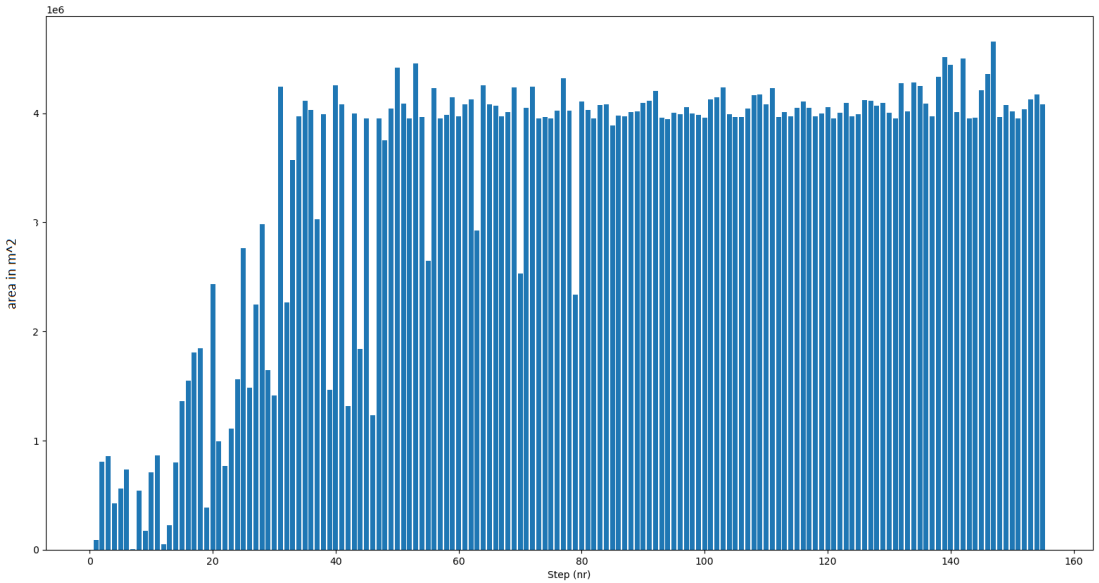

Figure: Total area of objects assigned to each parallel step of Option A.

Results

Option B

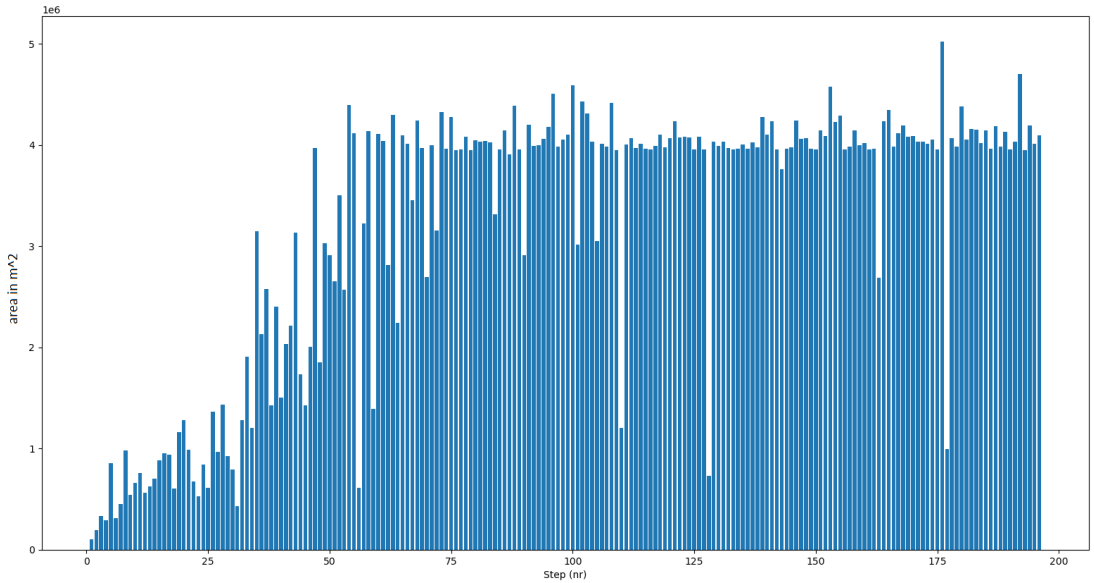

Figure: Total area of objects assigned to each parallel step of Option B.

Results

Option C

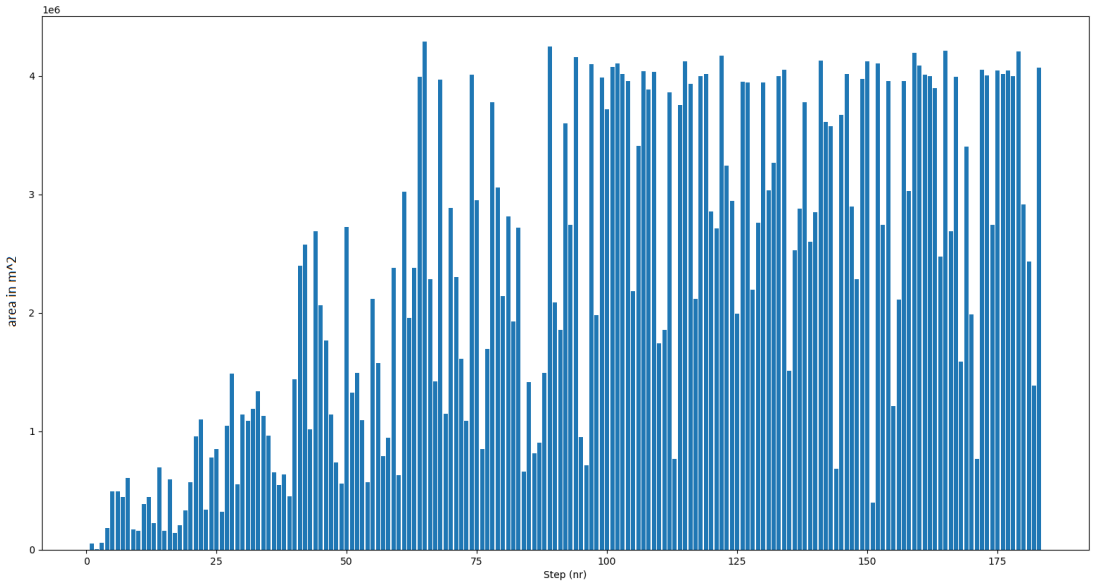

Figure: Total area of objects assigned to each parallel step of Option C.

Results

Assessment – parallel step assignment

Option	Variance	VMR
Option A	1609553	476
Option B	1845368	576
Option C	1439192	761

Figure: Variance and VMR for each tested option with 5% parameter.

Results

Assessment – parallel step assignment locally

Point	Circle	Option A		Option B		Option C	
		Var	VMR	Var	VMR	Var	VMR
Point 1	c1	23.45	3.99	19.63	4.43	27.27	7.93
	c2	88.12	4.03	78.29	3.06	35.13	6.45
Point 2	c1	22.7	3.92	24.63	4.47	56.28	9.81
	c2	75.18	3.62	74.04	3.17	43.7	5.97
Point 3	c1	25.53	4.22	32.11	6.54	44.80	10.56
	c2	74.45	3.62	88.47	3.98	29.7	5.98

Figure: Variance and VMR for each tested option and each local area.

Results

Assessment – accuracy of information preservation

Scale	Option A		Option B		Option C	
	steps	obj.	steps	obj.	steps	obj.
1:15000	51	2246	65	2216	33	2233
1:20000	92	4810	117	4769	96	4787
1:25000	114	5938	148	5966	127	5962
1:30000	130	6633	166	6601	150	6619
1:40000	141	7004	182	7002	180	7005

Figure: Table with a number of steps necessary to perform to create the maps at specific scales.

Results

Assessment – accuracy of information preservation

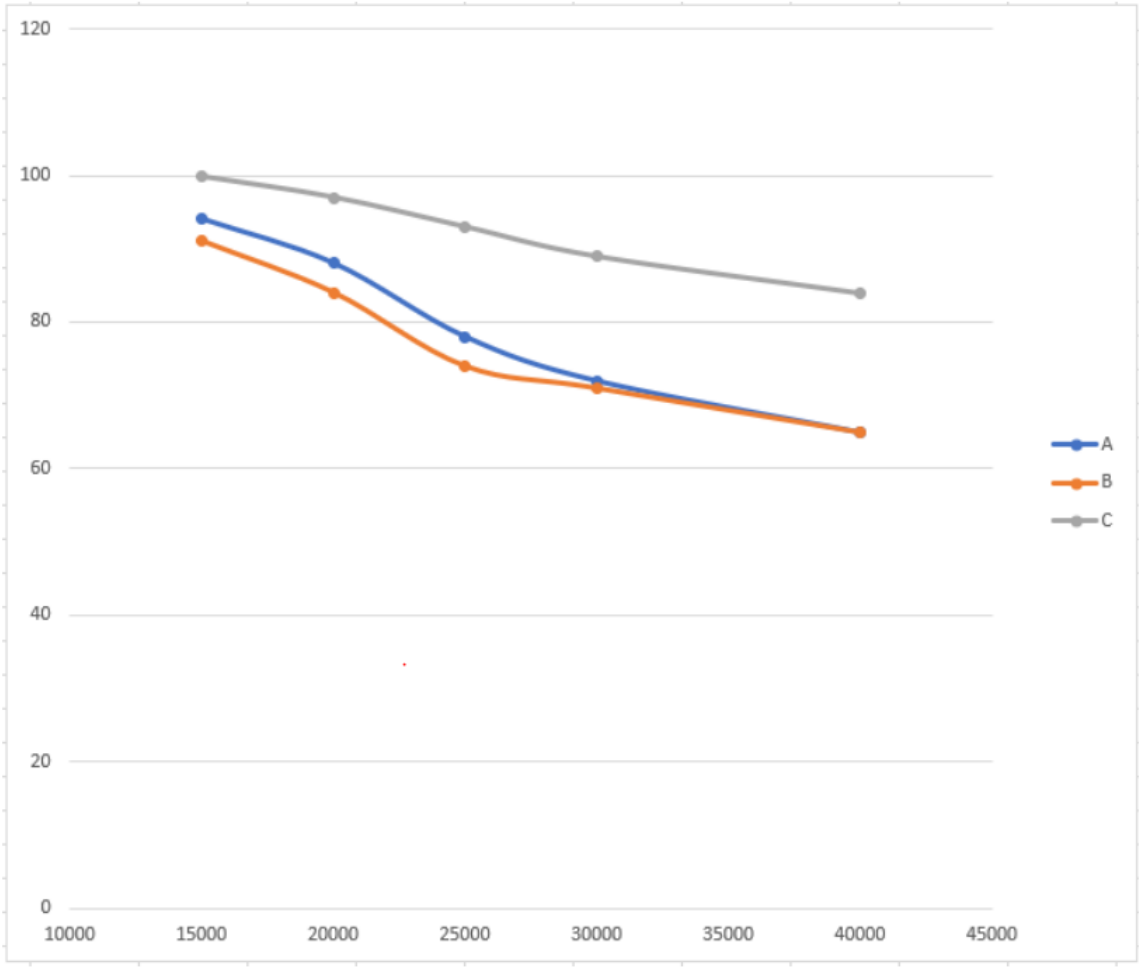

Figure: Overall accuracy of information preservation for each tested option.

Conclusions

Research questions

Question

Is it possible to see smooth transition of the map with the proposed improvement?

Conclusions

Research questions

Question

Is it possible to see smooth transition of the map with the proposed improvement?

Answer

Yes, it is possible to see smooth transition with all tested solutions and for all of them it can be concluded that the proposed solution improves the interaction between the map and the user in the predicted way.

Conclusions

Research questions

Question

Is the target map making the parallel step assignment distribution closer to expected?

Conclusions

Research questions

Question

Is the target map making the parallel step assignment distribution closer to expected?

Answer

Yes, provision of the target map has a significant impact on the parallel step assignment and makes it possible to distribute the objects more equally among specific steps based on the chosen ruling.

Conclusions

Research questions

Question

Does the target map make the spatial distribution of steps preserved locally?

Conclusions

Research questions

Question

Does the target map make the spatial distribution of steps preserved locally?

Answer

It is possible to see that the target map preserves it to some extent – the spatial distribution was slightly better in both of the approaches involving a target map compared to the classic approach.

Conclusions

Research questions

Question

What is the accuracy of the result classifications with respect to the initial map? Is there a difference between the tested approaches?

Conclusions

Research questions

Question

What is the accuracy of the result classifications with respect to the initial map? Is there a difference between the tested approaches?

Answer

There is a significant difference in the accuracy of information preservation between tested options and Option C seems to be more accurate, however it is also possible to notice a positive impact of the geometrical constraint on that matter in Option A and Option B – especially in the areas with dense road networks.

Conclusions

Research questions

Figure: The difference in preserving information between the provision of the target map and no provision of the target map.

Conclusions

Research questions

Question

What is the impact of the target map on accuracy? Is this solution feasible to be used in generalization process?

Conclusions

Research questions

Question

What is the impact of the target map on accuracy? Is this solution feasible to be used in generalization process?

Answer

It can be concluded that the geometrical constraint approach and its principles can be considered as suitable at this stage of development, however the ruling for the optimal choice of the final class needs to be changed.

Conclusions

Research questions

Question

What should the display time of every step depends on?

Conclusions

Research questions

Question

What should the display time of every step depends on?

Answer

It was concluded that the time should be the same for each parallel step and a specific value should depend on user preferences.

Conclusions

Research questions

Question

How to process the data for the purpose of web viewing?

Conclusions

Research questions

Question

How to process the data for the purpose of web viewing?

Answer

It can be concluded that the current state-of-the-art method is suitable for processing SSC with parallel steps and there is no need to alter it. However, during the research many problems regarding consistency of the data were noticeable, such as inconsistency of edges definition in case of Option A and Option B and it has to be taken into consideration if the user wants to use the currently implemented solutions.

Conclusions

Main research question

Main research question

What are the possibilities for a continuous generalization by parallel step assignment and how do they perform?

Conclusions

Main research question

Main research question

What are the possibilities for a continuous generalization by parallel step assignment and how do they perform?

Answer

- Parallel steps are a suitable way to show smooth transition on the map.
- Provision of the target map helps with assignment of changes among parallel steps.
- It seems it also has a positive impact on spatial distribution.
- It helps to preserve the information in some areas, however another condition for class of objects on the target map should be developed.
- In fact each tested option can be considered as a significant improvement of user-map interaction.

Online viewer and results examples

The results are available online, partially implemented as a web viewer and in the form of videos on the following web server:

kjarocki.github.io

References I

The most important positions

J.-H. Haunert. *Aggregation in map generalization by combinatorial optimization*. phdthesis, Leibniz Universität Hannover, Germany, 2009.

L. Huang, M. Meijers, R. Šuba, and P. van Oosterom. Engineering web maps with gradual content zoom based on streaming vector data. *ISPRS Journal of Photogrammetry and Remote Sensing*, 114:274–293, apr 2016. doi: 10.1016/j.isprsjprs.2015.11.011.

B. M. Meijers and P. J. M. van Oosterom. THE SPACE-SCALE CUBE: AN INTEGRATED MODEL FOR 2d POLYGONAL AREAS AND SCALE. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVIII-4/C21:95–102, aug 2011. doi: 10.5194/isprsarchives-xxxviii-4-c21-95-2011.

M. Meijers, S. Savino, and P. V. Oosterom. SPLITAREA: an algorithm for weighted splitting of faces in the context of a planar partition. *International Journal of Geographical Information Science*, 30(8):1522–1551, feb 2016. doi: 10.1080/13658816.2016.1140770.

D. Peng. *An Optimization-Based Approach for Continuous Map Generalization*. PhD thesis, University of Würzburg, 2019.

D. Peng, M. Meijers, and P. van Oosterom. Paralleling generalization operations to supportsmooth zooming: Case study of merging areaobjects. 2020.

References II

The most important positions

R. Suba. *Design and development of a system for vario-scale maps*. PhD thesis, A+BE — Architecture and the Built Environment, 2017.

R. Šuba, M. Meijers, and P. van Oosterom. 2d vario-scale representations based on real 3D structure. In *Proc. 16th ICA Workshop on Generalisation and Multiple Representation (ICAGM)*, Aug. 2013.

R. Šuba, M. Meijers, L. Huang, and P. van Oosterom. An area merge operation for smooth zooming. In *Connecting a Digital Europe Through Location and Place*, pages 275–293. Springer International Publishing, 2014. doi: 10.1007/978-3-319-03611-3_16.

P. van Oosterom. The gap-tree, an approach to "on-the-fly" map generalization of an area partitioning. In *GISDATA Specialist Meeting on Generalization*, 1993.

P. van Oosterom. Challenge the future delft university of technology. In *STW User Committee meeting,*. Oracle, 2012.

P. van Oosterom and M. Meijers. Towards a true vario-scale structure supporting smooth-zoom. In *Proceedings of the 14th Workshop of the ICA Commission on Generalisation and Multiple Representation & the ISPRS Commission II/2 Working Group on Multiscale Representation of Spatial Data, Paris*, page 19, 2011.

References III

The most important positions

P. van Oosterom and M. Meijers. Vario-scale data structures supporting smooth zoom and progressive transfer of 2d and 3d data. *International Journal of Geographical Information Science*, 28(3):455–478, dec 2013. doi: 10.1080/13658816.2013.809724.

P. van Oosterom and V. Schenkelaars. The development of an interactive multi-scale GIS. *International journal of geographical information systems*, 9(5):489–507, sep 1995. doi: 10.1080/02693799508902052.