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Automated generalisation of land cover data in a planar topographic map

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1. INTRODUCTION

This paper investigates two methods for generalising land cover polygons that constitute a planar topographic map (i.e. based on a data structure without gaps or overlaps). The issue of generalizing land cover objects is one of the main remaining issues identified in an internal proof of concept generalisation pilot by the Dutch Kadaster. In this ongoing research project a fully automated generalisation workflow is being set up for deriving small scale maps from TOP10NL data taking current requirements and new technologies into account (Stoter et al, 2009; Smaalen en Stoter, 2008). In 2010 the generalisation of 1:50k map from TOP10NL was prototyped, and further worked out in a successful Proof of Concept (PoC) in 20011 (see Figure 1 and Stoter et al, 2011). These results are currently being further developed to other test areas and other scales (first at scale 1:100k).

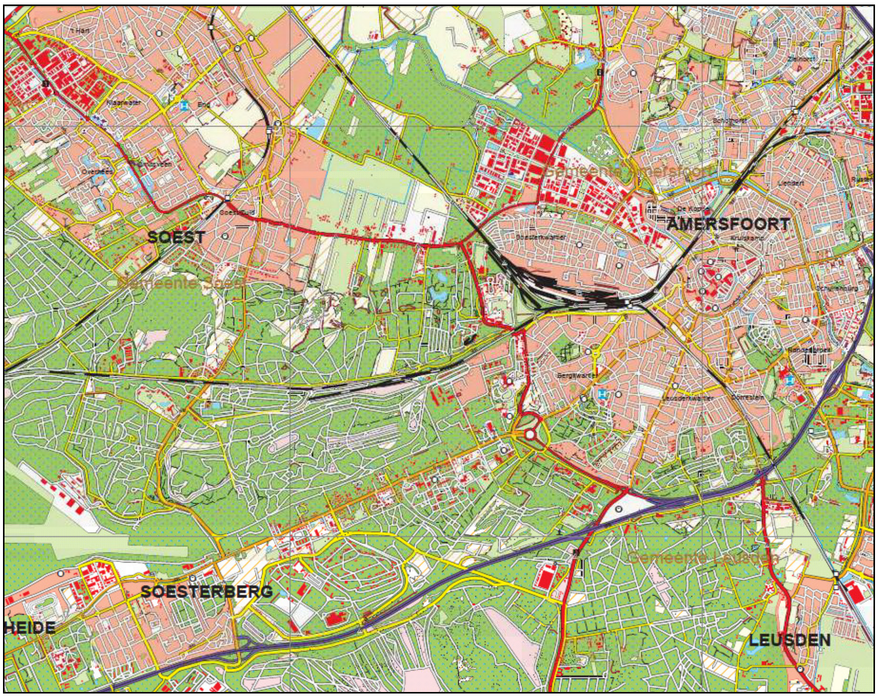


Figure 1: Results of the PoC: 1:50k map obtained by fully automated generalisation

The starting data, TOP10NL, is characterised by a planar partition of terrain, water, road (polygon) and railroad (polygon) features. Some of the (narrower) linear features such as ditches, footpaths and bicycle tracks are stored as lines in this dataset. Buildings are in a separate layer. In the generalisation of small scale maps from TOP10NL, land cover objects are the objects that remain after the physical objects as railway, roads, water bodies and buildings have been symbolised and displaced. Several algorithms are available to locate features in a sparse amount of space, for example Sester (2000), Bader and Barrault (2001), Bader (2001), Steiniger and Meier (2004), Legrand et al (2005), Monnot et al. (2007), Thom (2007). This paper does not focus on the best algorithm to displace, but how to best treat the land cover objects in this process.
The paper firstly details the encountered issue of land cover generalisation (Section 2) and secondly describes and evaluates two alternative methods that we are testing to solve the issue (Section 3). For each method initial results are presented as well. Section 4 ends with concluding remarks.

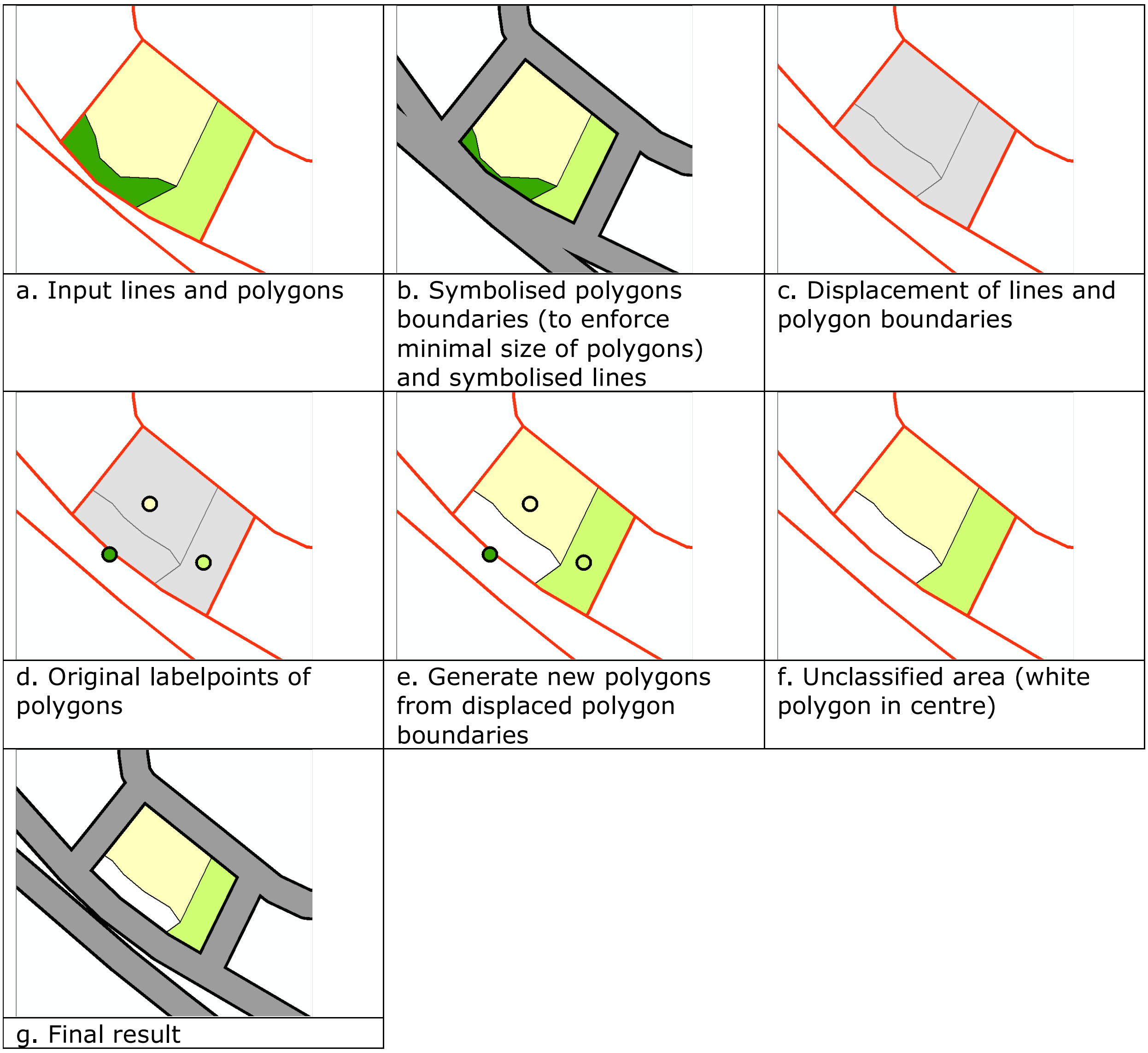
2. THE ISSUE OF GENERALISING LAND COVER OBJECTS IN A PLANAR PARTITION

As mentioned before, the automated generalisation of land cover objects was identified as issue that requires further research in the pilot that generalised a 1:50k map from TOP10NL data.
The main generalisation operations from TOP10NL to 1:50K map are firstly the conversion of most separate buildings in urban area into built-up area and secondly the collapsing of road and railroad polygons to lines (in TOP10NL these objects are stored as polygons *and* centerlines). After collapsing roads and railroads to lines, the adjoining terrain features (originally being part of a road) are reconnected to retain a planar partition. From scale 1:50k upwards roads and railroads - and to lesser extent waterways - are symbolised with an exaggerated width. In case of insufficient space these objects are displaced. Both the exaggerated symbolisation and displacement causes these objects to overlap the adjoining land cover area features. As a result the visible size of the adjoining features can become substandard (which may also be the consequence of the scale step). Hence we need a method to solve the conflict between symbolised linear network features, taking into account the visibility of notable adjoining area features.

3. TWO METHODS FOR LAND COVER GENERALISATION

In the generalisation tests we use ArcGIS 10. ArcGIS 10 offers some new tools for road displacement, building displacement and displacement propagation which are tested in our pilot (Punt and Watkins 2010). The intermediate results are discussed with the Esri development team to provide feedback how the tools work in practice. The tools are the first of a range of tools based on the optimizer technology (Monnot et al, 2007) and allow to build a workflow for cartographic generalisation with a choice of different methods.
For land cover generalisation we are testing two methods. Both methods start with the linear network features (dikes, railroads, roads, waterways, ditches) which are symbolised (Figure 1a,b & 2a,b). These linear network features are displaced relative to one-another using the *resolve road conflicts* tool (which also work on other objects than roads), see Figure 1c, 2c. The process uses a hierarchy of object types. Some object types are not to be displaced (dikes) or only as a last resort (railroads) whereas others are more likely to be displaced (smaller roads and waterways, ditches).
The difference between the two methods is the way the land cover data (forest, water, grassland etc.) is dealt with.

I. Displacement on linear network features including area boundaries
This method symbolises and displaces all linear features (including polygon boundaries), see Figure 1a-c. In a next step the attributes of the areas in between are reassigned. The method has been implemented in the 1:50k pilot in 2010 and is illustrated below on a small test data set, see Figure 2.



a. Input lines and polygons

b. Symbolised polygons boundaries (to enforce minimal size of polygons) and symbolised lines

c. Displacement of lines and polygon boundaries

d. Original labelpoints of polygons

e. Generate new polygons from displaced polygon boundaries

f. Unclassified area (white polygon in centre)

g. Final result

Figure 2: Displacement of all linear network features and land cover boundaries in a single displacement operation. And assignment land use codes of former polygons to newly generated polygons

In the method the boundaries of the land cover polygons are added to the displacement process for linear network features if they do not coincide with one of these network features. These boundaries do not have own attributes besides the hierarchy attribute that is added to define their degree of freedom in the displacement process. At the end of the

process the attributes of the original polygons - temporarily stored in the form of label points at the center of gravity of the original polygon - are reassigned to the polygons enclosed by the displaced polygon boundaries.
The advantage of this method is firstly that it is a straightforward and simple displacement process that operates on all linear map features in a single run (including roads, railroads, waterways and other relevant dividing features). Another advantage is that every polygon boundary is considered as a linear feature (Figure 2c). and therefore a separate process for exaggerating narrow area features can be avoided Instead the process assures that boundaries keep a minimum distance to one another, guaranteeing a minimum width of the area feature.
The main disadvantage of this method is reassigning the original attributes which can be difficult, especially if the new position of the object does not overlap with the old position. In some cases these boundaries may have shifted so far that even the center of gravity of an original polygon falls outside the area enclosed by its displaced boundaries (Figure 2d), which leads to unattributed polygons (Figure 2e-g). Currently we are studying a possible solution to this problem, i.e. assigning the attributes of the original polygons to the boundary lines used in the displacement operation instead of to the label points.

II. Linear network displacement followed by displacement propagation of area features

The second method symbolises and displaces the 'real' linear network features first such as roads, railroads and waterways (Figure 3a-c), but unlike the first method this operation does not include the land cover boundaries. The latter are included in a separate process comprising displacement propagation and exaggeration of the area features.
This method utilizes the set of displacement polygons which are optionally produced in the displacement process and that cover the area between the old position of a network segment and its new position (Figure 3d; compare to Figure 3a). The displacement polygons can be used in a subsequent *displacement propagation* operation to move the adjoining area features aside (Figure 3e). For this process it is crucial to define a hierarchy of importance for the polygon objects; objects that serve as reference points and landmarks in the landscape (mainly water bodies and forest patches) are to be displaced and potentially exaggerated at the expense of less notable objects (grassland, cropland, etc.).
An advantage of this method are that attributes do not have to be reassigned which may cause problems in the first method.
An issue with the method is that we may still need an additional process to enlarge (exaggerate) important but narrow features to their minimum width at the smaller scales (Figure 3f). Initial tests have shown that the *resolve road conflicts* may also be used to widen these narrow features (Figure 3g-j). Reassigning the original attributes based on the label points will not cause problems here since the label points are created based on the already displaced land cover polygons. This however needs further investigation.
The disadvantages of the method are due to the higher complexity of the method compared to the first method. Both the displacement of linear network features and the exaggeration of area features trigger a process of displacement propagation that can be difficult to handle. In addition the method may not work in areas where several important area features compete in a limited space.

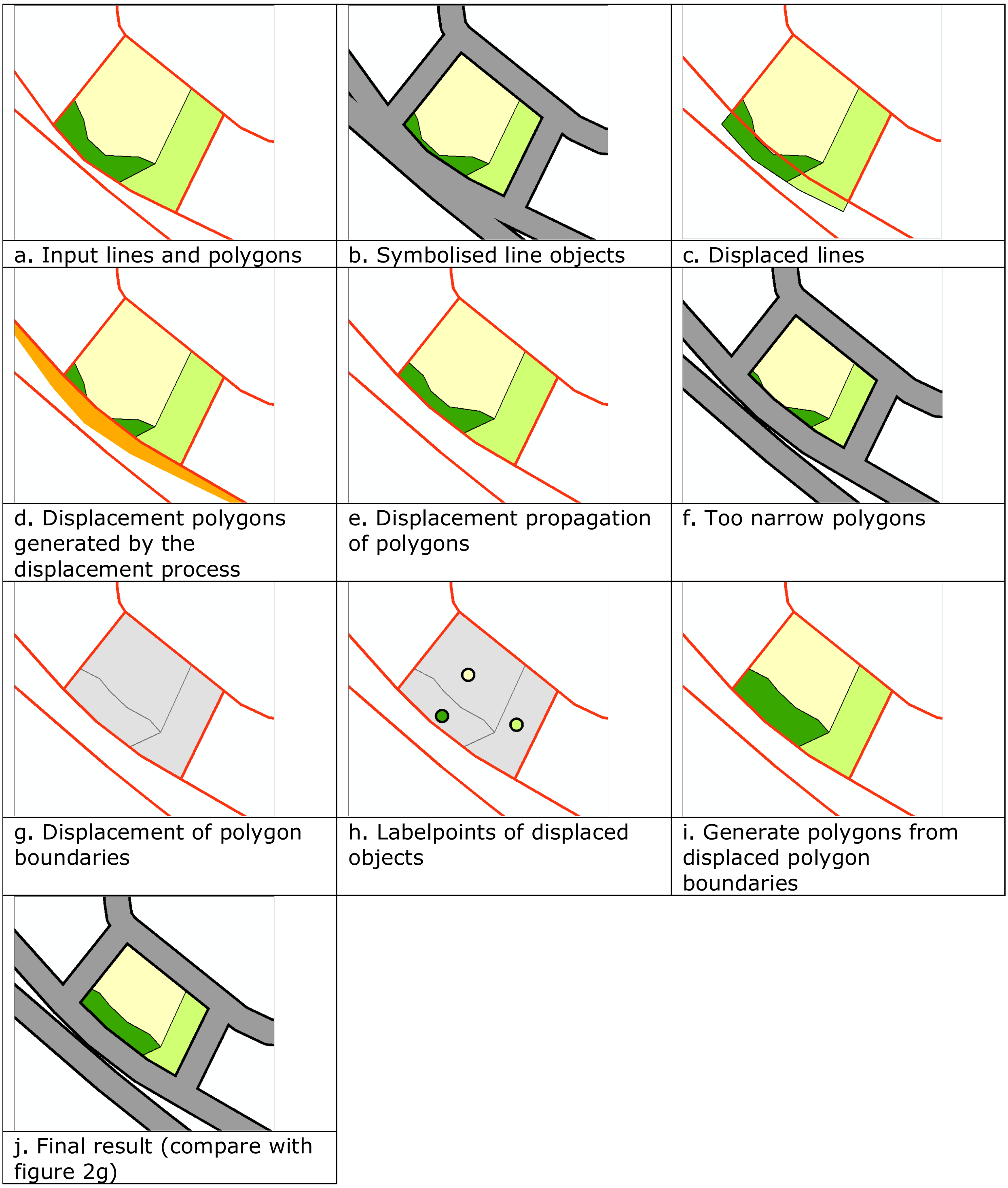


Figure 3: Step-wise displacement; first solving the conflicts between network features and subsequently moving the adjoining land cover polygons by means of displacement propagation.

4. CONCLUDING REMARKS

In conclusion, this paper explains two methods for land cover generalisation that are being tested as part of a bigger automated generalisation feasibility study performed by the Dutch Kadaster. Until now only the first of the two methods was investigated extensively in the generalisation tests from TOP10NL data to a 1:50k map. Those tests revealed the problems with this method as outlined above. Therefore ongoing research is deploying the second method which is the proposed workflow in the Esri software. The results will be compared with the results of the first method to select the best solution to generalise land cover data in a planar topographic map.

REFERENCES

Bader Matthias and Barrault Mathieu, 2001, Cartographic displacement in generalization: introducing elastic beams, in: Fourth workshop on progress in automated map generalisation, ICA, Beijing, China, August, 2001.

Bader Matthias, 2001 Energy minimization methods for feature displacement in map generalization (PhD thesis).

Legrand, Cristel, Duchêne Cécile, Lecordix François, 2005, Propagation of the displacements and deformations during a generalisation process,in: International Cartographic Conference, International Cartographic Association, A Coruna, Spain, July, 2005.

Monnot, Jean-Luc, Paul Hardy, and Dan Lee. 2007. "An Optimization Approach to Constraint-Based Generalization in a Commodity GIS Framework." Proceedings, ICA 2007. The 23rd International Cartographic Conference, Moscow, Russia. August 4-10, 2007.

Punt, E. and D. Watkins. 2010. user-directed generalization of roads and buildings for multi-scale topography, 13th ICA Workshop on Generalisation and Multiple Representation, 2010 Zurich

Sester, M. (2000) 'Generalization based on least-squares adjustment', International Archives of Photogrammetry and Remote, Sensing, 33, pp. 931–938.

Smaalen, J.W.N. van, J.E. Stoter. 2008. Automatische generalisatie van TOP10NL naar TOP50NL haalbaar?. In: Geo-info: tijdschrift voor geo - informatie Nederland (GIN), 5 (2008)2, pp. 48-53

Steiniger Stefan and Siegfried Meier, 2004 Snakes: a technique for line smoothing and displacement in map generalisationm in: workshop on generalisation and multiple representation, ICA, commission on map generalisation, Leicester, United Kingdom, August, 2004.

Stoter, J.E., J. van Smaalen, N. Bakker, P. Hardy. 2009. Specifying map requirements for automated generalisation of topographic data, The Cartographic Journal Vol. 46 No. 3 pp. 214–227 August 2009

Stoter, J.E., and Ron Nijhuis Marc Post Vincent Van Altena Jan Bulder Ben Bruns John Van Smaalen, 2011, Feasibility study on an automated generalisation production line for multiscale topographic products, accepted for 14th Workshop of the ICA commission on Generalisation and Multiple Representation, June, 2011, Paris

Thom, S, 2007, Stuart Thom, 2007, Automatic Resolution of Road Network Conflicts using Displacement Algorithms Orchestrated by Software Agents, ICA Workshop on generalisation and Multiple Representation, 2007, Moscow, Russia