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► **To cite this version:**

Jean-François Girres, Guillaume Touya. Cartographic Generalisation Aware of Multiple Representations. GIScience 2014, Sep 2014, Vienna, Austria. pp.289-291. hal-02288803

HAL Id: hal-02288803

<https://hal.science/hal-02288803v1>

Submitted on 16 Sep 2019

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Cartographic Generalisation Aware of Multiple Representations

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1. Introduction

Cartographic generalisation helps deriving maps at smaller scales from a detailed geographical dataset. It is more and more frequent to have at disposal several datasets at different levels of detail in a web mapping application. For instance, a source dataset is used for deriving maps from 1:50k to 1:250k and another less detailed dataset is used to derive maps below 1:250k. Deriving intermediate scales can be helpful to generate intermediate zoom levels in a multi-scale geoportal. However, current solutions only use one dataset as input, which may lead to inconsistencies when the user switches to maps derived from a different source dataset (Figure 1).

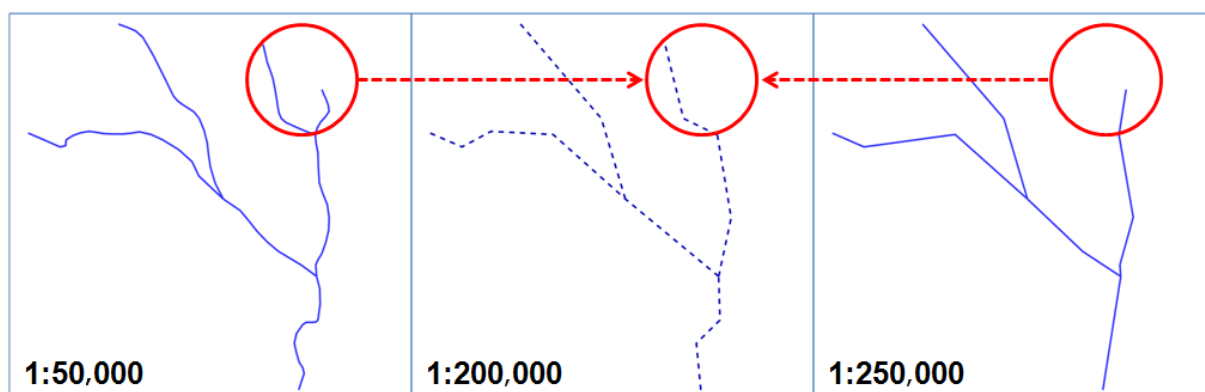


Figure 1: The intermediate scale (1:200k) is generalised from 1:50k but inconsistently with 1:250k.

The aim of the on-going research presented in this paper is to derive consistent intermediate cartographic representations to enable smooth transitions in a multi-scales geoportal. We call Multi-Representation Aware (MR-Aware) generalisation such generalisation. This work requires two major hypotheses:

- a multi-scales generalisation system to compute intermediate scales is available, like the ScaleMaster2.0 by Touya and Girres (2013), or the vario-scale model by van Oosterom et al. (2014),
- a data-matching system (e.g. Mustière and Devogèle 2006) has been used to link objects at different levels that represent the same real world entity.

The second part of the paper describes different scenarios to achieve MR-Aware generalisation. The third part describes experiments on real data and the fourth one draws some conclusions and explores further work.

2. Scenarios for Handling Multiple Representations during Generalisation

2.1 Post-processing Strategy

The first possible strategy for handling multiple representations during generalisation is to apply post-processing corrections that modify the generalised data in order to preserve consistency. There are two alternatives: a simple one and a complex one. The simple alternative is to identify the inconsistencies in the generalised output (Figure 2a) and then use the next level representation to enrich the generalised output. In Figure 2, the inconsistency is a missing river that is added in the post-process.

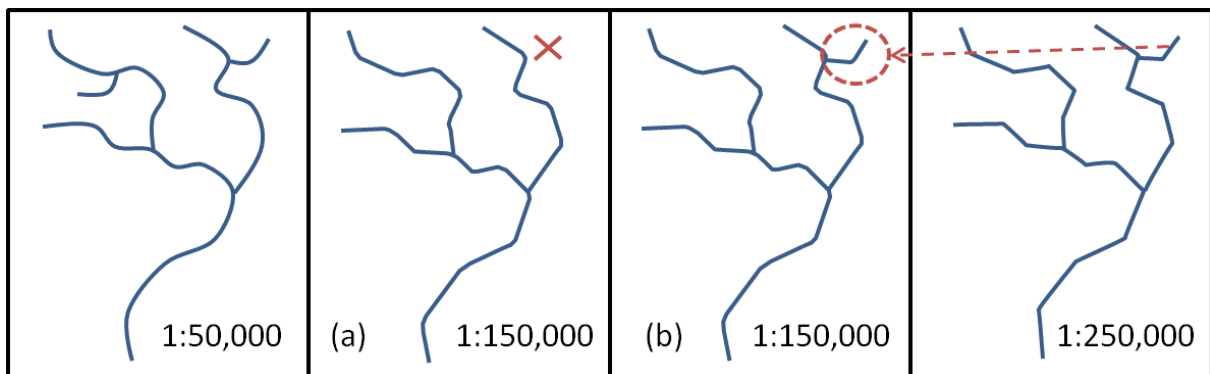


Figure 2: Post-processing strategy: the forgotten river (a) is added after generalisation at 1:150k from the 1:250k level data (b).

This scenario tends to increase the amount of data in the generalised output, which is not desirable. The second alternative is a more complex post-process that deals with this problem by reducing the amount of data after consistency has been achieved. In Figure 2, it would remove another river that is not present at the 1:250k level.

2.2 Pre-processing Strategy

The second strategy seeks to handle consistency between scale levels before generalisation. Once again, two alternatives are discussed. The first one consists in identifying the objects in the initial level that are linked to an object in the upper levels, and then apply generalisation only on those objects that are not linked (Figure 3): matched objects cannot be deleted as they are not processed by generalisation.

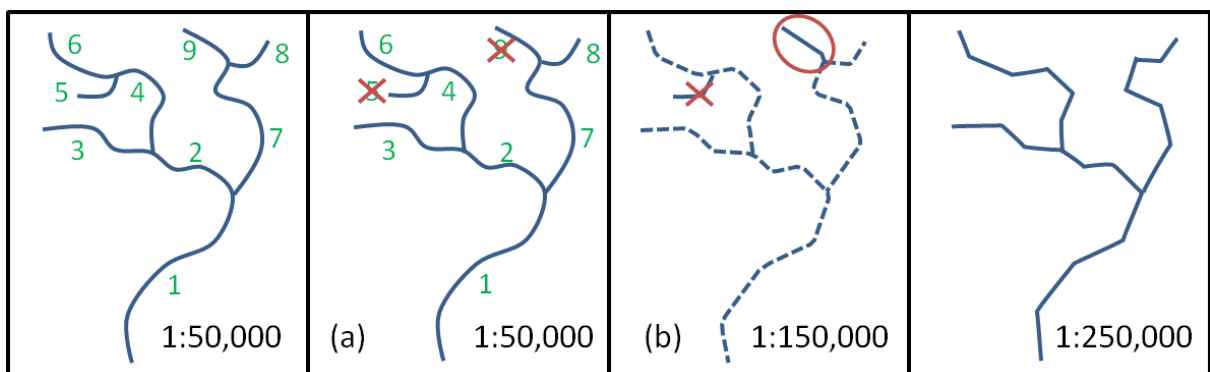


Figure 3: Pre-processing strategy: (a) the unmatched objects (5 and 9) are identified (b) selection is computed on unmatched objects only (5 is deleted and 9 is kept).

The second alternative is quite different from all other strategies, as it involves the modification of the generalisation process, while the others just provided adaptations to what a generalisation process can achieve. With this strategy, the matched objects are a complementary input of the process that has been changed to cope with a set of matched objects and a set of unmatched objects. For instance, instead of just simplifying the geometry of a matched object, the modified process will instead compute an intermediate geometry between the detailed and the undetailed matched geometries.

2.3 Scenarios Comparison

All four scenarios have advantages and drawbacks. They are analysed in relation to the quality of the MR-aware generalisation they can provide, and to the cost of their implementation in a given multi-scales generalisation system. The best scenario in terms of output quality is the last one that modifies the generalisation processes to take matched objects into account. Unfortunately, it is also the most costly scenario as it requires the re-implementation of each generalisation process, which is sometimes not possible, for instance in a system based on external generalisation web services (Regnauld et al. 2014). On the other hand, the simpler scenario is the post-processing addition of missing objects. We believe that the worst theoretical scenario in terms of output quality is the first pre-processing strategy where only the unmatched features are generalised. As generalisation is a holistic process, removing the neighbours of an object may lead to poor generalisation results. Finally, the most balanced scenario is the post-processing strategy that preserves consistency as well as the final amount of data in the map.

All four scenarios are sensible to the errors of the matching process, but the sensibility of each scenario to omission and commission has to be studied further.

3. Experiments

To illustrate MR-aware generalisation (using post-processing strategy), an experiment is provided on a sample of road networks extracted from datasets at 1:50k and 1:250k (Figure 4). A preliminary matching of homologous road objects was achieved using the Mustière and Devogèle (2006) algorithm.

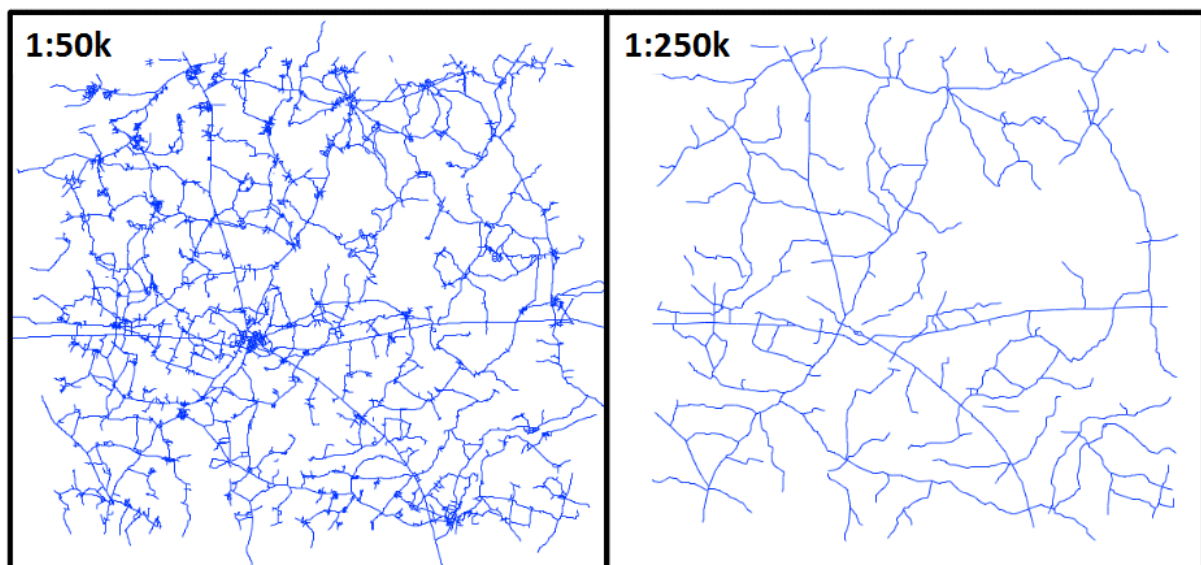


Figure 4. Road networks extracted from 1:50k and 1:250k datasets

In order to generalise an intermediary road network at the scale 1:150k, strokes-based generalisation is carried out (Thomson & Brooks 2000). The process is applied with and without MR-aware generalisation. Figure 5 shows the roads which have been preserved (in green) by MR-aware generalisation, but would have been eliminated without (in red).

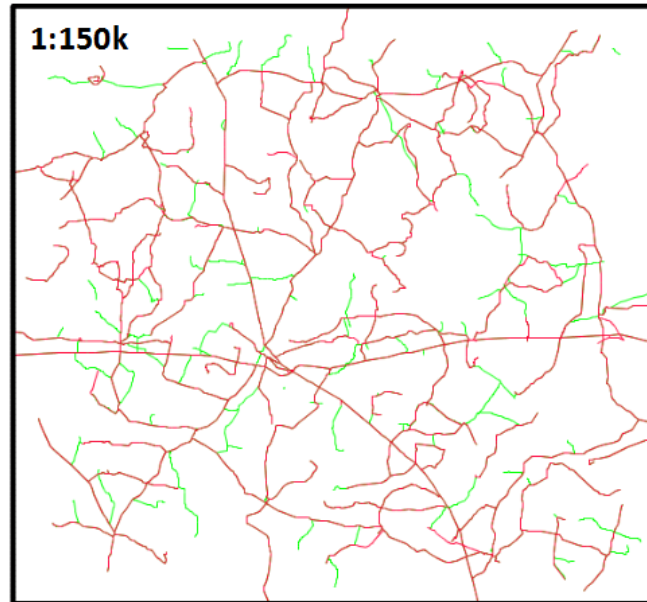


Figure 5. A road network (1:150k) without (red) and with (green) MR-aware

To quantify these differences, Table 1 exposes the difference in object numbers and roads total length, between both original datasets and the generalised road network with or without MR-aware generalisation. The results show that more than 400 km would have been deleted by not applying MR-aware generalisation.

Table 1. Comparison of generalised roads with or without MR-aware.

Dataset	Number of objects	Length (km)
<i>Roads 1:50k</i>	6512	5039,76
<i>Roads 1:150k (without MR-aware)</i>	2264	2041,64
<i>Roads 1:150k (with MR-aware)</i>	2713	2476,88
<i>Roads 1:250k</i>	812	1768,39

A second experiment was carried out on railroad network generalisation (Touya & Girres 2014) with a comparison of the strategy where only unmatched features are generalised and the previously tested post-processing strategy (Figure 6). Both strategies provide better results than only generalisation, and in this case, pre-processing deletes more features as removing the matched features damages the geographic context used by generalisation.

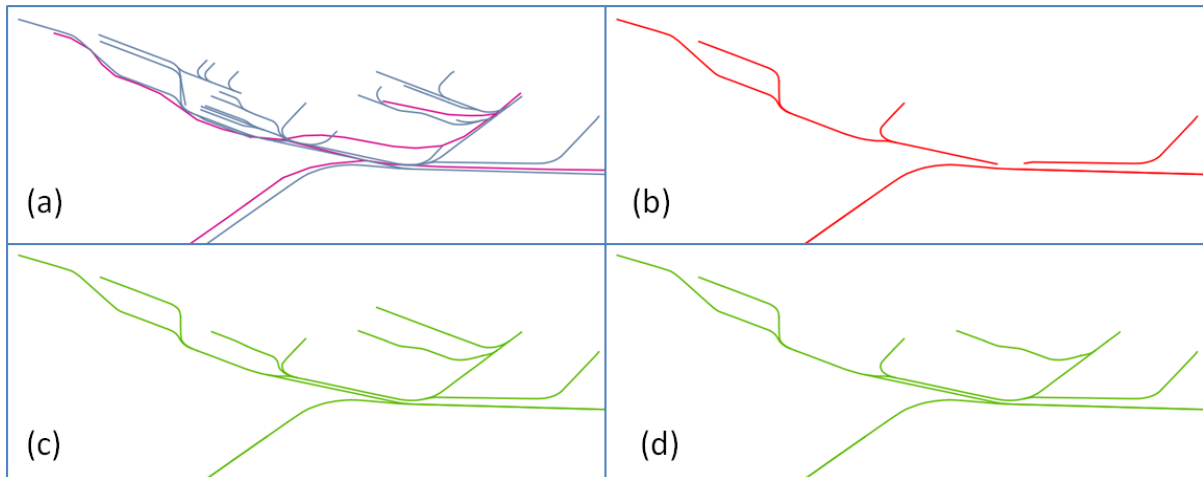


Figure 6. (a) railroad network at initial scales (1:50k in blue, 1:250k in magenta). (b) generalisation without MR-aware process. (c) post-processing MR-aware generalisation. (d) pre-processing MR-aware generalisation.

4. Conclusion and Further Work

This paper proposed different scenarios to enable the derivation of consistent intermediate cartographic representations between existing multi-scale levels. Two of the scenarios have been implemented and tested on real datasets, with promising results.

As the presented work is on-going research, there is much to explore. First, both implemented scenarios were tested with simple generalisation processes, and further testing should be made with more complex processes. For instance, polygon to line collapse (Figure 6) should be hard to handle with the post-processing strategy. Then, all four strategies should be tested and compared to get a clearer view on the best strategies.

Generalisation is a holistic process that requires the modelling of the geography around each object, notably the spatial relations with neighbours. Roads are drawn in a map to show they allow the access to some place, so geographical context has to be integrated to MR-aware generalisation to improve the quality of intermediate levels.

Finally, the proposed scenarios do not handle inconsistencies between levels, which occur with real datasets. In Figure 4, the bottom left road of the 1:250k dataset does not exist at 1:50k. It is not possible here to preserve consistency.

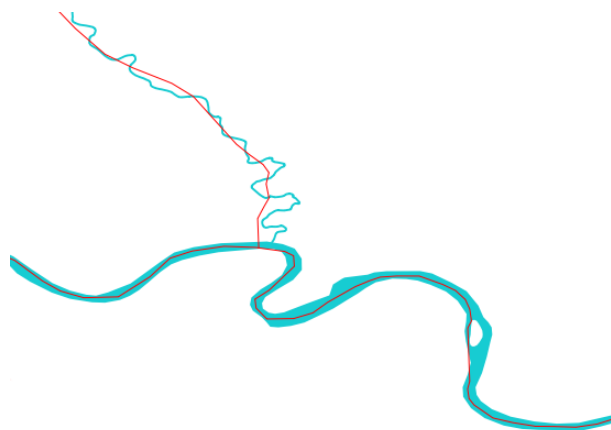


Figure 6. Rivers represented by lines and polygons at 1:50k and by only simplified lines at 1:250k.

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