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Strategies for pan-scalar map generalisation

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Abstract

Interaction is at the centre of pan-scalar map design (Gruget et al., 2023), as it allows the user to navigate between diverse representations at various scales. However, these maps are not only collections of independent maps but are an interactive system where the user navigates to see more or less detailed information. In this context, map design has to be redefined to fit the current way of using maps. The specific nature of pan-scalar maps has been investigated with two approaches, 1) by analysing the design of existing maps such as Google Maps or the default OpenStreetMap pan-scalar map (Gruget et al., 2023), and 2) with user surveys (Wenclik and Touya, 2023). This leads to some first attempts to improve map design, for instance with additional representations (Dumont et al., 2023). However, there is still a lack of propositions on how to change the map generalisation processes used to control the level of detail and legibility at a particular scale. The purpose of this article is to explore several generalisation strategies for the creation of a pan-scalar map.

The goal of generalisation in pan-scalar maps should be to make the maps easier to use and explore. To fit this objective the map generalisation must provide the most adapted level of information at each zoom level. This assumption leads to several guidelines on pan-scalar map generalisation.

- **G1: Continuity** Changes must be distributed in the whole range of zoom levels, thus each pair of consecutive zoom levels changes a little, but no pair contains huge changes. This would increase the continuity during navigation between zoom levels. The conceptual cusps (i.e. the changes in how geographic information is abstracted Mackaness et al. (2014)) must be placed across the different zoom levels. The breaks caused by cusps alter the continuity of the representation of one theme, but they are necessary to reflect a hierarchy of information in space.
- **G2: Spatial distribution** The changes must be homogeneously distributed in the map. Indeed, changing only one portion of the map at one scale may cause an attentional capture effect (i.e. our attention is attracted to the area that changed obfuscating the rest of the map) during the zoom, resulting in disorientation. In addition, we want to avoid empty spaces in the map, because empty spaces do not contain any landmarks to guide the navigation and help orientation. Also, empty spaces do not nudge users to zoom.
- **G3: Inconsistencies** It is necessary to choose generalisation processes that avoid inconsistencies between scales (Girres and Touya, 2014), or at least use a post-process that checks consistency after the derivation of all scales.
- **G4: Focus on pattern** Compared to static cartography, we must focus less on graphic conflict resolution as the user can always zoom in or out to resolve them. On the contrary, we should focus more on structures and patterns, which provide landmarks to guide navigation and help orientation.

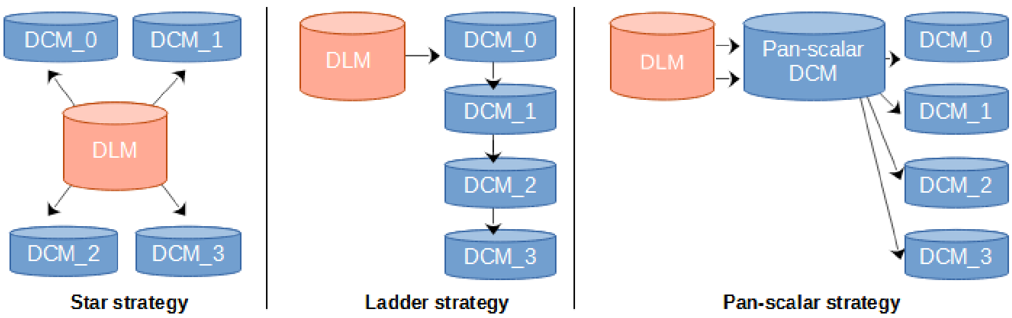

Figure 1. Illustration of different strategies

For deriving several consecutive zoom levels or digital cartographic models (DCM) from a unique digital landscape model (DLM) two strategies are possible: a ladder strategy, i.e. the data at zoom level $n-1$ is used to generalise zoom level n, instead of using each time the initial zoom level; or a star strategy, i.e. the map at each zoom level is directly derived from

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the initial DLM (Stoter, 2005). We claim that the star strategy is less adapted to a pan-scalar output as it may produce inconsistencies and less continuity between the different zoom levels (**G1 and G3**). Moreover, a pan-scalar strategy that orders the transformations and then decides at which zoom level each transformation occurs should be preferred (Figure 1). Finally, we claim that to respect guideline (**G1**), the pan-scalar DCM should be created by enriching the DLM with multiple representations and hierarchies derived from multiple generalisation processes; we should not try to derive a continuous pan-scalar DCM with a unique algorithm. Then, zoom levels are created by choosing the relevant entities in the pan-scalar DCM.

Then, we illustrate this strategy with a few examples. The first example is applying this strategy to the interactive selection of water lines. The pan-scalar DCM is enriched with the semantic information from the topographic database (persistence and width) and indicators calculated on the river network with automatic algorithms (stroke, braided or main channel, Horton order, etc.). For each zoom level, we identify the relevant criteria for selection: e.g. at large scales, we first remove braided streams and streams that are not persistent, but this information is irrelevant at smaller scales. Then, thresholds are empirically defined, following a ladder strategy. Finally, at each scale, manual corrections are performed to ensure a relevant spatial distribution of changes and focus on pattern **G2 and G4**.

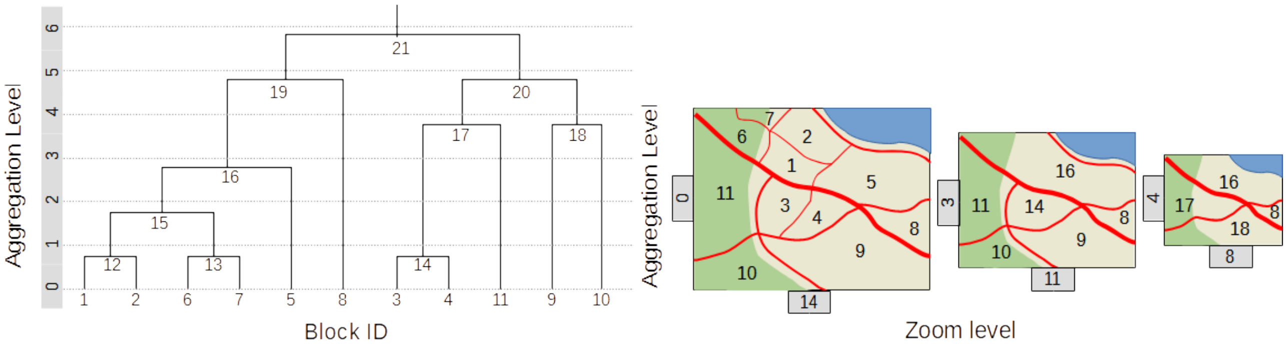

Figure 2. An example of a dendrogram for multi-scale block aggregation and corresponding zoom levels.

The second example is the adaptation of a classical road selection algorithm for pan-scalar purposes. We choose to adapt the algorithm from Touya (2010) where the selection of the road network in urban areas is modelled as a multi-criteria decision problem: which contiguous urban blocks should be merged at a given scale? This aggregation decision is based on the compactness of the aggregated block, the centrality of the road, the traffic estimation, and the length of the stroke carrying the road. The base algorithm is iterative and respects **G2 and G4**. We modify it to construct a dendrogram of block aggregations based on the same cost function, from which several zoom levels can be derived (Figure 2). This process avoids multiple aggregations of one block at one aggregation level (i.e. level of the dendrogram) and ensures a homogeneous distribution of the aggregations across the scales, without creating inconsistencies **G3**. Moreover, to control the progressiveness of block selection (**G1**), the list of aggregation candidates and the maximum aggregation cost are calculated as a function of the aggregation level. For instance, for higher levels, bigger blocks with a more important cost can be aggregated.

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