Does Generalisation Matters in Pan-Scalar Maps?

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Abstract

Maps and their usage have widely evolved recently, to become more and more interactive, multi-scale and accessible. However, the design of maps did not change so much, leading to the following two problems: (1) in theory, it is not formalised how to create a good map in this context, (2) in practice, the most used maps are not good considering the quality criteria defined for the classical (static) maps. Therefore, it is necessary to question the usefulness of these principles in this new context. In this article, we focus on the role of cartographic generalisation in maps where one can easily zoom in and out to make information accessible. We draw up a list of hypotheses on the role of generalisation for pan-scalar maps, based on both a deductive approach (the role of map generalisation is deduced from a review of human-maps interactions), and an inductive approach (observation of maps with diverse qualities). Then, we discuss how these hypotheses might be experimentally verified.

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1 Introduction

Map generalisation (MG) is the process of deriving a map at a certain scale from detailed geographic information. This process is an important step in designing a static map at a specific scale. However, most maps used today are not static paper maps at a specific scale or even a stack of independent static maps but pan-scalar maps [7]. "Pan-scalar map" refers to interactive zoomable applications comprised of numerous maps of a particular area at different zoom levels (i.e. scales), and we assume that the generalisation of such maps involves new challenges compared to traditional map generalisation. Today, a broad audience can easily access many maps from a computer or mobile device. In parallel with the multiplication of cartographic media, the time spent on each has decreased and the user expects ever faster and more easily accessible geo-information. We could think that a simple response to this need would be to use more and more generalised maps, as MG reduces the level of detail, hierarchises and simplifies the information in each view. In practice, we rather observe the contrary: Google Maps, for instance, is globally chosen by users although it includes many views with a lousy generalisation, an ill-adapted level of detail, and remaining conflicts. This observation raises the question if MG still matters when you can just zoom in to see more details or zoom out to see less.

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The goal of this article is to refine the usefulness of MG in the current context, by examining how the quality of MG may affect users during the exploration of pan-scalar maps. We first review how pan-scalar maps are used, then we review the graphical consequence of a bad generalisation and their impact on map usage and finally, we draw up a list of hypotheses on map generalisation usefulness and discuss how they can be verified.

2 How do people use maps?

Maps are often defined as communication models to convey geographic information, and the most general usage of maps is the acquisition of spatial knowledge [11]. Understanding map reading strategies for spatial knowledge acquisition in pan-scalar maps involves both the understanding of the reading strategy for each view [1] and the understanding of the navigation strategy. In this context, an exploration is a set of successive views and transitions triggered by interaction (e.g. zoom-in, zoom-out, pan) [14]. For each new view of the exploration, a reconciliation is performed to associate the information of this view with the one from the previous views (present in short-term memory), and the user's previous knowledge (present in long-term memory). This step is both achieved from information observed pre-attentively and attentively and the feeling of disorientation in a pan-scalar map is provoked by contradictory or missing information during reconciliation. Thus, MG can affect disorientation by its impact on the representation of entities used for reconciliation.

Moreover, the typification of cartographic usage is an important subject in spatial cognition and the usage of the map may widely affect the exploration strategy and thus the role of generalisation. For instance, thematic maps represent and locate phenomena in relation to the environment; and their generalisation should highlight spatial relations between the phenomena and their context and their different magnitudes across scale [5]. Consequently, the exploration should contain a few interactions and longer views. On the contrary, route planning is often made from topographic maps and involves many interactions: zoom out on the complete path; zoom in on arrival, departure place and complex intersection; pan along the route etc. In this case, the role of generalisation is to preserve road hierarchy and connections necessary for route planning and avoid disorientation at each interaction.

3 Map generalisation and pan-scalar maps

Map generalisation is the adaptation of the level of detail at a certain scale. This reduction of the level of detail should enhance legibility while preserving the main structures and patterns at the target scale. The role of MG in the usability of static maps has been formalised years ago, and to our knowledge, it was never updated for pan-scalar maps. Some studies already demonstrate the impacts of some map design choices (related to MG) on the efficiency of pan-scalar map exploration (e.g. landmark visualisation [4]), while others focus on the adaptation of legibility thresholds used in MG for screen display [12].

Currently, most pan scalar maps are created with generalisation strategies that do not differ so much from those used for papers map: (1) the range of possible scales is split into a defined number of representations (2) each is generalised independently (with a variable quality) (3) intermediate views are derived by enlarging the closest representation. This process does not take into account pan-scalar map specifics. Indeed, it aims to make each view legible not to optimise navigation between scales. Recently, there is some focus on smooth navigation [6, 15]. However, the role and usefulness of generalisation have not been investigated in a pan-scalar environment. In the next paragraphs, we review the possible effects of a bad MG in this context.

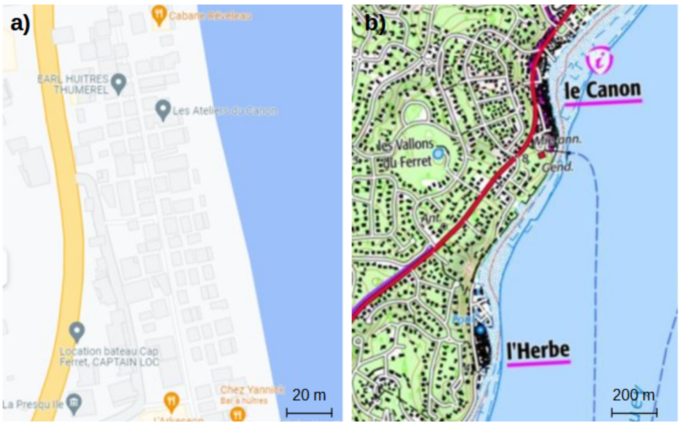

Figure 1 Example of conflict that can remain after a bad generalisation. a) overlaps between buildings and roads disconnect the road network b) overlaps between buildings.

The impact of remaining graphical conflicts. First, map generalisation is often viewed as a method to resolve graphical conflicts occurring when cartographic information is rendered. A conflict is when a constraint cannot be respected (e.g. two objects overlap or an object is too small, see Figure 1). In a pan-scalar map, contrary to a static map, when a conflict occurs the user can access the hidden information by just zooming in until the conflicts disappear and thus it has less impact on the usability of the map. However, more interactions are required which is not practical, and some information theoretically visible at a certain scale can be hidden (e.g. in Figure 1.b, the two cities cannot be compared in one view). This practical question of quantity of interaction conduces to more cognitive load and more opportunity for disorientation. It may also affect the trust of the user in the map and map provider. Would you trust a map with many unsolved conflicts?

The impact of missing information. A bad generalisation may involve a loss of information: in some map views, entities are removed to avoid conflicts while it would be possible and relevant to make this information appear without conflicts with a relevant generalisation. The absence of information can be of several types: (1) the entity is not represented (2) a geometric part of the entity is missing, e.g. a notch or a meander is removed, which prevents entity recognition (3) the semantic granularity of the entity is not sufficient, e.g. in Figure 2.a. the green space is not specifically symbolized as a stadium. On one hand, such problems may hide some phenomena or information, and affect the decision-making made from the map. For instance, could you find sports facilities in Figure 2? On the other hand, it affects the exploration of the map, as some views/scales are not useful by themselves, they are just intermediate steps in the exploration, requiring more interaction overall. It may produce more disorientation and less confidence for users (1) if expected landmarks are not present, or (2) if you need to zoom too much to see the missing information.

The impact of clutter. Contrary to the previous point, a bad MG can also produce too much and too complex information. Clutter is a notion of image complexity, cluttered images tend to increase the cognitive load [8], and we observe a similar impact of clutter for map images [9]. To better understand the effect of clutter on pan-scalar map usage we can make an analogy with a messy and cluttered room, where you have to search for a particular object; even with the ability to zoom in and out, it would be easier to find the object if the room

Figure 2 Illustration of missing information. a) Google map only represents the roads and green areas in this view. b) OSM depicts more information.

Figure 3 An area mapped at a regional scale to illustrate the absence of hierarchy: a) OSM: very few entities are salient, and no structure stands out. b) IGN map with more hierarchy.

were organised. In a similar way memorising the position of an object is easier, and the user may experience less disorientation as the landmarks are easily identifiable and memorable between scales. Finally, we could hypothesise that cluttered maps are less accessible to the general public and require a higher level of expertise. Indeed, an expert may dedicate more time to reading the map, already knows some reading keys etc. For instance, geological maps are often cluttered, but still useful for experts.

The impact of the absence of hierarchy. Finally, map generalisation provides a hierarchy of information. Indeed the goal is not only to reduce information density and level of detail but also to highlight the main information and preserve and enhance structures and patterns. With static maps, this is mostly made by a gradual use of visual variables (e.g. size, colour) to improve salience (e.g. toponyms for cities appear with a size relative to their importance; important roads appear larger and with a brighter colour than a local road). Hierarchy is used to structure and or partition the space in a view, thus its absence makes that each entity is presented with the same level of importance. It may lead to a sense of disorientation when there is no salient landmark (see Figure 3) or when an important pattern cannot be extracted (e.g. Paris ring road does not stand out from the road network in OSM). Further than the disorientation, it is really difficult to memorise or to project yourself into a map without a hierarchy of information. Moreover, in a pan-scalar map a second factor of hierarchy exists and can be employed: the scale of appearance [7]. For now, the hierarchy in the common pan-scalar map is also unsatisfactory as structures do not appear clearly: for instance, important toponyms appear too late to avoid placement conflict, which causes confusion and cognitive load [6].

4 Measuring the effects of a good map generalisation

In the previous section, we identified several effects of map generalisation on pan-scalar map use. We review here these elements and try to identify how to measure their impact via a user test where users are faced with maps with variable quality of generalisation.

H1. Practicality. is characterised directly by the number and the range of interactions that compose an exploration. This is simple to measure and can be measured from whatever task.

H2. Disorientation. is a feeling, it can be measured by asking the participant (either with a questionnaire or think-aloud). Both strategies have drawbacks: the feeling is instantaneous so a questionnaire afterwards could be ill-adapted; a think-aloud strategy is shown to distract users from the exploration and combines very badly with eye-tracking. Then, disorientation can be indirectly measured via induced behaviours: a disoriented user may search for landmarks and thus make large saccades across the map, or zoom out strongly. Disorientation may occur in most of the tasks but it can be a tenuous phenomenon compared to all other cognitive process in play during a pan-scalar map exploration.

H3. Cognitive load. directly degrades user attention and may cause a decrease in task performance. It can also be indirectly observed by an increased number of eye blink [3]. To measure a cognitive load the task proposed to the user must be complex enough and repeated enough to cause this cognitive load.

H4. Memorisation. is the quantity and quality of remaining information after an exploration. It is commonly tested with two types of tasks: recall and recognition [2].

H5. Confidence. is the feeling of user self-confidence and confidence in the map producer during exploration and decision-making. To our knowledge, the only way to measure it is using a self-report questionnaire.

H6. Accessibility. is the level of map reading skill necessary to understand and make good decisions from the map. Measuring map reading skills is challenging. Commonly it is associated with the sense of direction, which can be estimated via self-report measures [10] or via spatial perception, mental rotation and spatial visualisation tests [13]. This skill varies in an important range in a population, thus even without a reliable estimation, it is possible to verify this hypothesis with the variability of user response for a task: the variability might be smaller for a map with good generalisation (even users with low map reading skills might succeed as well as experts). The number of participants required to observe such a variation might be important.

5 Conclusion: Does generalisation matters in pan-scalar maps?

We identified six hypotheses on the usefulness of map generalisation for pan-scalar maps: practicality, disorientation, cognitive load, memorisation, confidence and accessibility. Experimental verification of these hypotheses is crucial to design improved pan-scalar maps. However, it is a significant research challenge due to the variety of map usage, and incompatible measures. We propose the following plan: 1) Practicality and confidence can be investigated using a widely distributed study that measures user interaction and feelings for realistic map usage. 2) Disorientation and cognitive load are studied in an in-situ survey using eye tracking. 3) Memorisation and accessibility are verified with long sessions on a specific population with various expertise levels. These three surveys are essential to discern the role played by map generalisation in the optimal use of pan-scalar maps and to guide future map generalisation research towards usability rather than tradition.

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