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A methodological inquiry for anchoring pan-scalar maps

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Abstract. This paper reports two experiments for the design of anchored pan-scalar maps. Anchoring pan-scalar maps means improving the saliency and memorability of some cartographic elements, i.e. the pan-scalar anchors, to enhance the navigational cues that can be used for self-localization during or after a zoom in a map. Within this article, concrete examples illustrate the process of adding anchors at different locations in the map, or how map designers can extend the scale range where anchors are salient. The paper concludes by highlighting the practical implications of this research for mapping professionals, offering a clear path for the creation of more effective anchored pan-scalar maps.

Keywords. mental map, map generalization, pan-scalar map, drawing, anchor, sketch map

1 Introduction

In this research, the focus is on the use of what is termed as pan-scalar maps, referring to interactive, zoomable, multi-scale maps such as Google Maps (Gruget et al., 2023). Users often experience disorientation or navigational trauma (Harrower and Sheesley, 2005) when using these maps, and the lack of consistent navigational cues or anchors across different scales is identified as a potential cause of this disorientation (Touya et al., 2023). The hypothesis is that within the virtual environment of pan-scalar maps, certain map objects can function similarly to anchors or landmarks in a real space, aiding in spatial orientation. In this context, the Seine River, the Ring Road or the Eiffel Tower can be perceived as map components that users may memorize while exploring a pan-scalar map around Paris through zooming and panning because they remain salient and visible across multiple scales (Figure 1). The ease of memorizing and retrieving these elements helps users self-localize while navigating the map. These significant map elements are referred to as pan-scalar anchors, by analogy with the anchor theory in spatial cognition (Couclelis et al., 1987). A recent eye-tracking study supported the idea that users look at pan-scalar anchors before, during, and after a zoom (Wenclik and Touya, 2023).

If pan-scalar anchors favour self-localization and reduce cartographic disorientation, the consequence should be to increase the number and salience of anchors in these pan-scalar maps. This is what we call anchoring a pan-scalar map, and this is the question addressed in this paper. After a more precise definition of this anchoring process, the paper reports two experiments to anchor a pan-scalar map, with local and a global perspective.

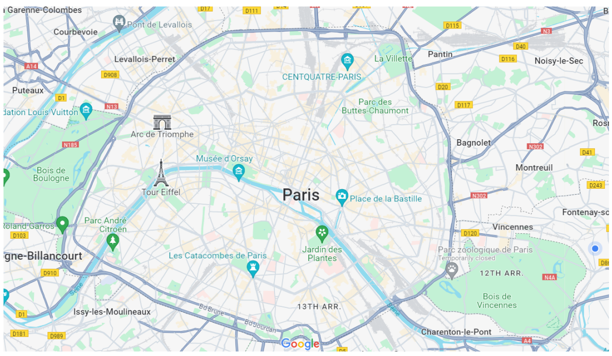

Figure 1. Map view of Paris at zoom level 12 with Google Maps style.

2 What does it mean to anchor a map?

We define the process of anchoring a pan-scalar map as the increase of the number and the saliency of pan-scalar anchors in the map. But what are pan-scalar anchors exactly? "A pan-scalar anchor is a cartographic symbol, group of symbols or spatial relation between symbols that is salient or recognisable in all the maps at several consecutive zoom levels" (Touya et al., 2023). For instance, in Figure 1, we can see text (Paris toponym), point symbols (the Eiffel Tower and the Arc of Triumph monuments), a group of lines (the Ring Road), or a group of polygons (the Seine River) as salient features, so they are good candidates for being used as anchors if their saliency is stable across at least several scales. As we can see in this example, some anchors are naturally present in pan-scalar maps, because these maps combine visual hierarchies (with some symbols more salient than others), and features that remain on the map when the scale changes. However, those natural anchors are not always sufficient for self-localization, so we can consider the map anchoring process as an enhancement of the natural anchors in the map.

Figure 2. Three consecutive zoom levels with Google Maps style centred on Paris. The Ring Road is a persistent anchor at these scales, but the Seine River saliency fades as the scale decreases.

We can define different forms of anchoring a map:

- *improving anchors saliency*. The anchors may be naturally salient in the map with the default style and map generalisation level, but not salient enough to be immediately striking when looking at the map. In this case, anchoring the map means emphasizing the visual hierarchy, by adjusting the style or changing the level of detail of the anchors.
- extending the scale range of some natural anchors in the map. For instance, Figure 2 shows three consecutive zoom levels of Google Maps, centred on Paris. While the Ring Road remains a salient anchor across these three zoom levels, the Seine River, salient at zoom level 11, fades as the scale decreases, and the map would be better anchored if the river remained salient at these two zoom levels.
- *adding anchors in scale ranges lacking visual hierarchy*. For instance, the default OpenStreetMap style creates map views without a clear visual hierarchy between zoom levels 10 and 13, besides the primary roads (Figure 3). Increasing the saliency of the large rivers and the significant cities would better anchor the map at these scales.
- *adding anchors in regions lacking visual hierarchy*. The global legends of current pan-scalar maps are mostly focused on western centres of activity, and some other areas may appear empty in these maps. And if all anchors are gathered in the big cities, exploring the rural regions will cause more disorientation. Thus, anchoring the map also means that we fill these empty regions with a few anchors.
- *favouring spatial relations between anchors to create a reciprocal enhancement of their saliency*. To serve their role as anchors during the exploration of the map, the anchors are even more efficient if they are spatially related to each other, as they better triangulate space. Anchors that cross each other, or anchors inside other anchors should be more efficient.

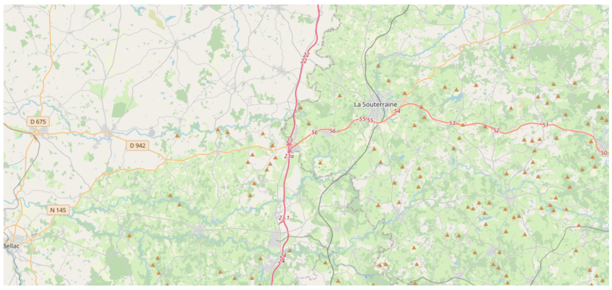

Figure 3. Extract of OpenStreetMap at zoom level 11, centred on a rural area where the visual hierarchy is rather flat apart from the primary roads in red (©OpenStreetMap contributors).

Anchoring a map could also be achieved by adding artificial navigational cues such as grids (Dickmann et al., 2017), or regular crosses (Korte et al., 2023), as both improve our memory performance with maps. However, in this paper, we only focus on enhancing geographical objects from the map to anchor it.

3 A methodological inquiry anchoring pan-scalar map: Use case on Madison, WI, USA

In this section, we report an attempt to anchor a pan-scalar map. The use case is local, i.e. the anchored map is supposed to be browsed from zoom levels 12 to 17, centred on the city of Madison, Wisconsin, USA, starting from a Google Maps initial style. In the next sections, we describe the use case, and our method to decide which elements of the map should be enhanced as pan-scalar anchors.

3.1 Description of the use case

Even though pan-scalar maps are usually worldwide maps, we started with a local use case, where the anchors are adapted to the local geography and the salient features of the landscape, to further derive more global rules on how anchors should be highlighted in worldwide or continent-wide maps. Our map covers the city of Madison, Wisconsin, USA from zoom level 12 to zoom level 17 (Figure 4. It is possible to zoom in even more, but the map is not anchored anymore at these scales that cover a very small portion of space. As Google Maps remains the most used pan-scalar map due to its ubiquity on Android smartphones, we decided to use this initial style to be anchored. To facilitate the creation of the new map, we use the default Google Map as a background and add layers on top of it. But a better version of the anchored map would use the vector data to generate a new map. The browsable anchored map is provided as additional data (see Section 4.1).

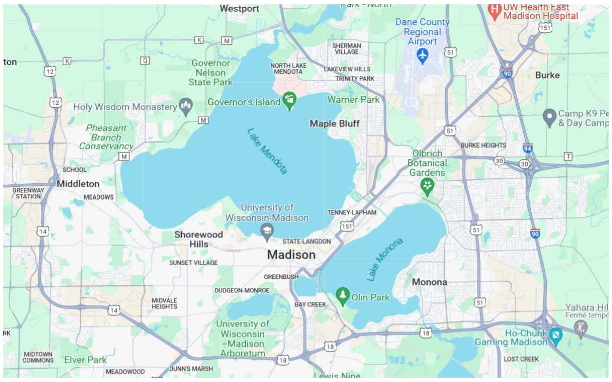

Figure 4. Madison, Wisconsin, USA, at zoom level 12, the smallest scale considered in our use case (Source: Google Maps).

3.2 Anchoring the Madison map

The first step is to make a perceptual inventory of a panscalar map space. The aim is to assess the remarkable existing elements of the current map and to study their stability across scales. To do this one cartographer draw 8 sketch maps on pen and paper. Sketch maps are one of the methods to recall map-related information from memory since they spatialize the extracted information from a cognitive map (Billinghurst and Weghorst, 1995; Keskin et al., 2018). Sketch maps also have characteristics similar to current cartographic generalization processes (Manivannan et al., 2022). Indeed, drawing allows us to eliminate what is not important and to extract and accentuate, more or less consciously, what is essential; it establishes an inventory of elements, becomes a means to find new perceptual configurations, highlighting what is memorable, and amplifying what is imagined (Tversky and Suwa, 2009).

From these sketch maps, we derive what we call skeleton maps, or digital sketch maps (Keskin et al., 2018) (Figure 5) by digitizing them in a GIS. The background map is used to geolocate the skeleton map but is not displayed when the geometries are digitized to keep the abstract and generalized characteristics of the sketch maps. This process is reproduced for all the zoom levels from 12 to 16.

The sketch map at zoom level 12 shows that the road network and the lakes are remarkable, and this remarkability also seems to persist at scales 13 and 14 (Figure 5). The peninsula in the northern lake and the capitol square become visible at zoom level 13 only and are completely remarkable from zoom levels 14 to 16. This sketch maps elements inventory is used to create an "Anchor Scale Line" (see Section 4) reporting the range of scale where each anchor is prominent (Figure 6).

Map skeletons first also allow us to identify regions lacking visual hierarchy. For example, in the urban space between the northern lake and the southern horizontal road axis, no anchors have been identified at any scale. To solve this problem, we add the train line as an anchor salient at all scales in our range (Figure 7).

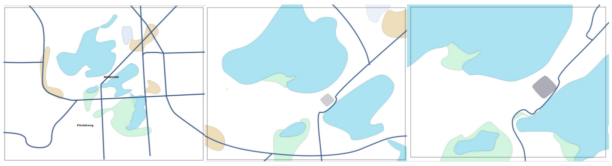

Figure 5. Skeletons maps on Madison at zoom 12,13,14 centered on Madison.

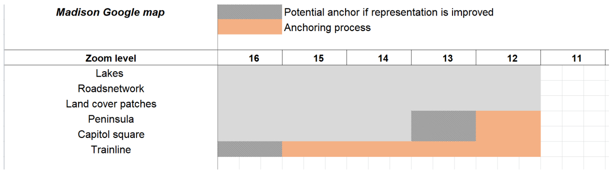

Figure 6. Summary of the anchors in the Madison area with the Google Maps style. the light grey shows the scales where the anchors are already salient; dark grey shows scales where the saliency of the anchor should be improved; orange shows scales where the anchoring process could add/extend the anchor.

To extend the saliency of the peninsula and the capitol square, we once again used the sketch/skeleton map technique. For example, if we analyze the skeleton map of the peninsula, we may notice simplification or caricature processes (Figure 8). Geometries are smoothed, and dropouts are filtered out. There are also selection/elimination processes, with interior roads omitted and POIs eliminated. Sketch maps also caricature geometries. For example, 4 expansion/deformation processes can be identified, notably that of the strip diving into Lake Mendota. We can also see that the bay, the upper junction and the two main roads have undergone geometric enhancement. The bay has been rounded, the road and the upper junction squared, and the junction between the arm and the land has been slimmed down (Figure 8). We then anchored the peninsula, following the characteristics identified in this annotated skeleton map. We directly use the skeleton object as the object appearing at zoom level 12 then for zoom level 13 we perform a process of alignment between the skeleton and the background map (Manivannan et al., 2022) (Figure 9).

3.3 From local to global anchors

Once the anchors have been identified from a local perspective, the question may be the extension to a global scale. To what extent the structure we chose can be found in other places? Thus, the question is not only what the anchor is, but what is the essence of the anchor. What makes the peninsula in Lake Mendota, or the capitol square so remarkable (Figure 10), its length and width ratio? Ring roads are another interesting example: their characteristics can be extracted from a user survey to understand what a clear and salient ring road is Potié et al. (2022). We believe that sketch mapping can help to identify what makes an anchor and may help the transition from local to global

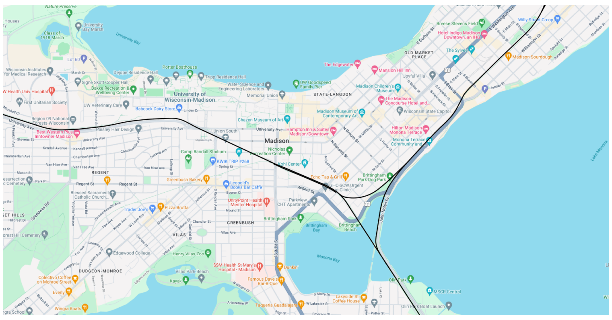

Figure 7. Anchoring the train line in regions lacking visual hierarchy in Madison (background map: Google Maps).

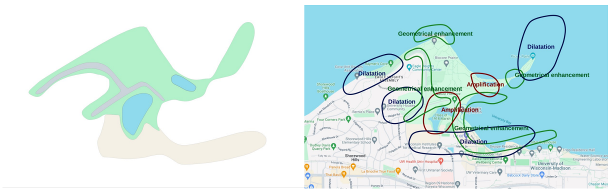

Figure 8. Comparison of the skeleton map with the cartographic view and annotation by cartographic generalization processes.

anchors. In this sense, what could greatly help the pan-scalar designer would be to automate the detection of anchors that are not directly derivable from the data, in the globality of a pan-scalar map, e.g. the ring roads from the previous example.

4 A Scale Line of Anchors

To better approach a global anchoring process, i.e. anchoring a map to a continent-wide or worldwide extent, we report another experiment to create a "scale line" of anchors. Adapted from the ScaleMaster model (Brewer and Buttenfield, 2007), the scale line of anchors is a timeline where scale replaces time, and the scale range where each anchor is salient and prominent can be reported as one line in the scale line (Figure 11). The following method was adopted to fill this scale line. First, we selected three pan-scalar maps: Google Maps, the default OpenStreetMap map, and a map retrieved from a national mapping agency (NMA) geoportal (anonymised for review). The point of scanning three different maps was to identify both common and specific anchors. Two experts independently scanned each of these three maps, by freely zooming in and out. When they pointed one anchor, they had to scan each consecutive zoom level to define the scale range where this anchor remained salient. Then, the two experts discussed their own choices to combine them into a single scale line. Apart from the salient anchors, they also identified potential anchors if the style or the generalisation was different. These last cases are interesting because they can be seen as primary targets for the anchoring process.

The scale line of anchors produced with this method is too large to be presented directly in the paper, but a spreadsheet is provided as additional data (see Section 4.1). From this scale line of anchors, we can make the following remarks:

- very few point and text symbols are selected as anchors from these three maps. For text, it can be explained by the joint lack of generalisation to create hierarchies of text elements and efficient text placement techniques. As a consequence, the three studied maps adopt small text symbols, which reduces their potential saliency. We believe that these two types of symbols could be better used to anchor the map.
- all scales can be partly covered by anchors. Though anchors are different at small and large scales, which is not surprising. Some anchors cover the complete range of scales studied but with features of different sizes. For instance, the peninsulas or isthmus are striking anchors but the large ones such as Florida or Korea are anchors at very small scales, while the isthmus Rewski in Poland is significant at medium/large scales (Figure 12).
- The differences between the three styles are minimal. There are a few anchors that are specific to one of the three maps, e.g. the points of interest in Google Maps at zoom levels 15 to 12, or the high summits in Google Maps at zoom levels 9 and 10. There are also a few cases of anchors that are salient in only two out of the three studied maps, e.g. the train lines between zoom levels 16 to 12 are only salient in the OSM and NMA maps.
- Main rivers, train lines, and mountain ranges are good targets for the anchoring process. The scale line shows that all these types of features are salient at multiple zoom levels, but their scale range could be extended to make them better anchors. For instance, main rivers such as the Danube (Figure 13) are not salient anymore at zoom levels 11, 10 and 9 in OSM and Google Maps, mainly due to a lack of map generalisation (if the river symbol is wider, there will be

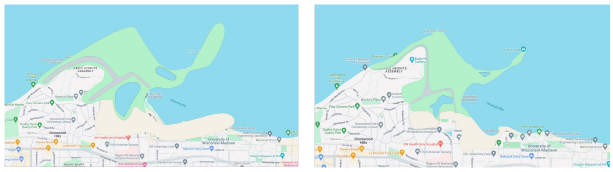

Figure 9. Alignement of the skeleton from zoom level 12 to 13.

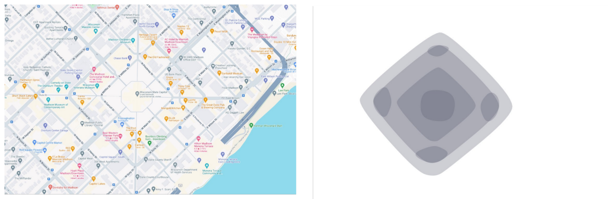

Figure 10. Skeleton map of the capitol square

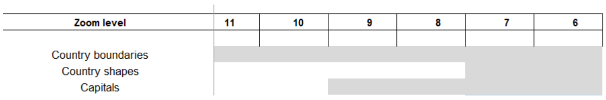

Figure 11. Extract of the scale line of anchors with three different types of anchoring features with the scale range, in grey, for each of these types.

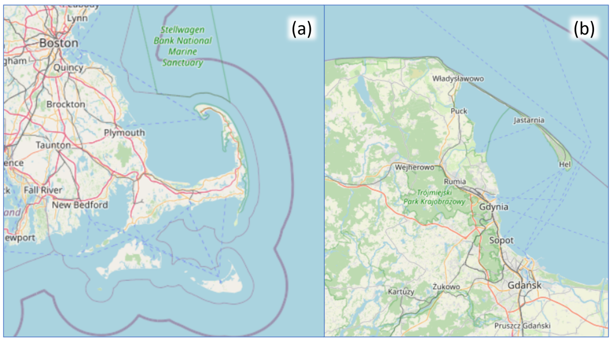

Figure 12. Two extracts of OpenStreetMap showing salient isthmuses with different scale ranges due to their respective size: (a) Cape Cod in Massachusetts, USA; (b) Rewski isthmus in Poland (©OpenStreetMap contributors).

symbol overlaps with roads and other symbols and displacement operations will be required).

Figure 13. Extract of the OSM pan-scalar map at zoom level 10 where the Danube is not clearly visible despite its geographical importance. An anchoring process would make the river more salient by widening its symbol (©OpenStreetMap contributors).

4.1 Dataset

The dataset presented in this paper is available on Zenodo (https://zenodo.org/records/10671724). Note that a second use case map, not described in the paper, is provided in this dataset.

5 Conclusion

We very much believe that the presence of common features across pan-scalar map scales would reduce disorientation phenomena in pan-scalar exploration. The anchoring of a pan-scalar map can be thought of in a local way (characterizing anchors specific to one environment) or in a global way (characterizing anchors or characteristics that may be common to a variety of cartographic environments). This paper reports two experiments that illustrate these local and global views of the anchoring process.

However, the two reported experiments are only the first steps in the understanding of this map anchoring process. In particular, user studies are required to measure the impact of anchoring on memory and disorientation, and then to identify the best way to anchor a pan-scalar map. Which are the best anchors to enhance a world-scale pan-scalar map? How much anchoring is too much? Are new automatic map generalisation techniques required to extend the saliency of the important anchors across more scales?

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Competing interests. The authors declare that no competing interests are present.

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