A Context Frame for Interactive Maps

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Abstract

Digital maps are ubiquitous, supporting countless online activities. Most interactive mapping platforms support three user operations to move across space: zooming in, zooming out, and panning. While using interactive maps, it is common for users to land in an unfamiliar area at high zoom levels. To understand the location of the area, users zoom out, identify known objects, such as large cities and other landmarks, and zoom back into the target area, an operation known as *confirmation of relative position*. This operation is cognitively complex, time-consuming, and prone to cause disorientation. This article outlines a generic framework to support map navigation by placing contextual information around the map, bridging the on- and off-screen spaces. The proposed framework allows the dynamic generation of spatial cues in a *context frame* in the map that shows objects located *outside* of the map, reducing the need for relative positioning. The approach is based on an algorithm that ranks the prominence of nearby objects, and is illustrated in a case study about a small Italian town. This framework can also support cognitive mapping, showing spatial relations between geographical objects in a novel way. The source code and a demo of the framework are available online.

Keywords: confirmation of relative position, web mapping, cartography, map context, map interaction, marginalia

Source code & demo: https://github.com/andrea-ballatore/map-context-frame

1 Introduction

Interactive maps are a ubiquitous medium to search for and consume geographic information (Ballatore et al. 2016). Web maps, both on web browsers and increasingly on smartphone apps, enable the visualisation and understanding of the surface of the Earth in a growing number of tasks, ranging from wayfinding to the spatial exploration of data for diverse domains, including transportation, logistics, urban planning, climate science, and environmental management (Roth 2013, MacEachren 2004). Across all platforms, screen sizes, input modes, and technical implementations, the basic operations that enable map use include zooming in, zooming out, and panning.

When interacting with digital maps, it is common to land in an unfamiliar area, for example when opening a Google Maps search result. To understand the location of an unfamiliar target area (e.g. Vicolo del Gallinaccio in Rome), users must refer to some known location (e.g. the Trevi Fountain or the Quirinal Palace). As the context of the area shown in the map remains off-screen, users unfamiliar with an area must perform some operations for positioning what they are looking at. In their work on sequences of map operations, Hiramoto & Sumiya (2006) identify *confirmation of relative position* as a sequence of zoom out and zoom in operations aimed at locating known objects and landmarks.

Figure 1 shows an example of relative positioning of an Italian town with respect to larger and better-known cities. As a way to acquire contextual information, relative positioning is cognitively complex and time-consuming. It requires a large scale transition across zoom levels (from urban level to country level and back), as well as a repositioning operation, in which it is possible to lose track of the target area, unless explicitly marked.

The remainder of this article proposes a novel, generic framework to support the relative positioning task. The JavaScript source code and a demo of the framework are available online[1] under a Creative Commons license. The framework enables the creation of a context frame around the visible part of the map that refers to objects outside of it, allowing for positioning, reducing the need for zooming operations. To populate the context frame, the approach selects and places objects using a hybrid strategy. The approach is illustrated using cities as notable objects on a web mapping prototype.

2 Related work: The map context

The display of information in interactive maps has attracted considerable research over the past 20 years in human-computer interaction and GIScience, building on classic work in cartography (MacEachren 2004, Roth 2013). Much cartographic research focusses, understandably, on what is visible in the map. However, representing what is missing is equally important, and attracts attention to the crucial problem of the map's representational limitations and arbitrary omissions (Robinson 2019).

Some approaches come to mind to tackle the lack of spatial context in maps, whose margins mark an arbitrary end to the continuous surface of the planet. Overview maps are commonly used as navigational aids, showing the context of the target area in a smaller map. While being common in interactive maps, they show limited benefits in empirical evaluations (Hornbæk et al. 2002), also because of the constrained amount of information that can be displayed. Visual cues about targets outsides the

[1] https://github.com/andrea-ballatore/map-context-frame (All URLs were accessed in December 2018)

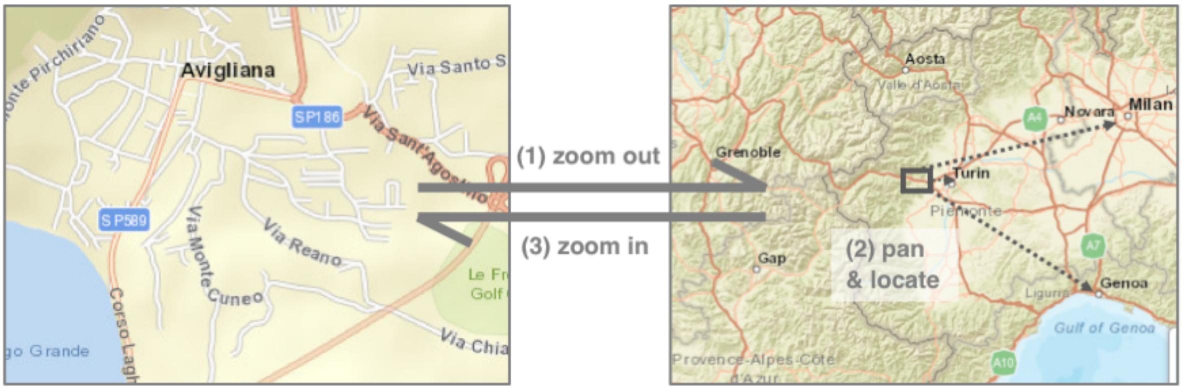

Figure 1: An example of relative positioning. The target area is on the left (an Italian town called Avigliana), covering about 2.5 km^2. The reference area on the right shows a much larger area that contains the target (about 180 km^2). When the user is presented with the figure on the left and does not know the location of the target, it is necessary to perform relative positioning: The user (1) zooms out, (2) locates the target with respect to known objects (e.g. Turin, Milan, and Genoa), and (3) zooms back in. Sources: Leaflet (map), ESRI (map tiles).

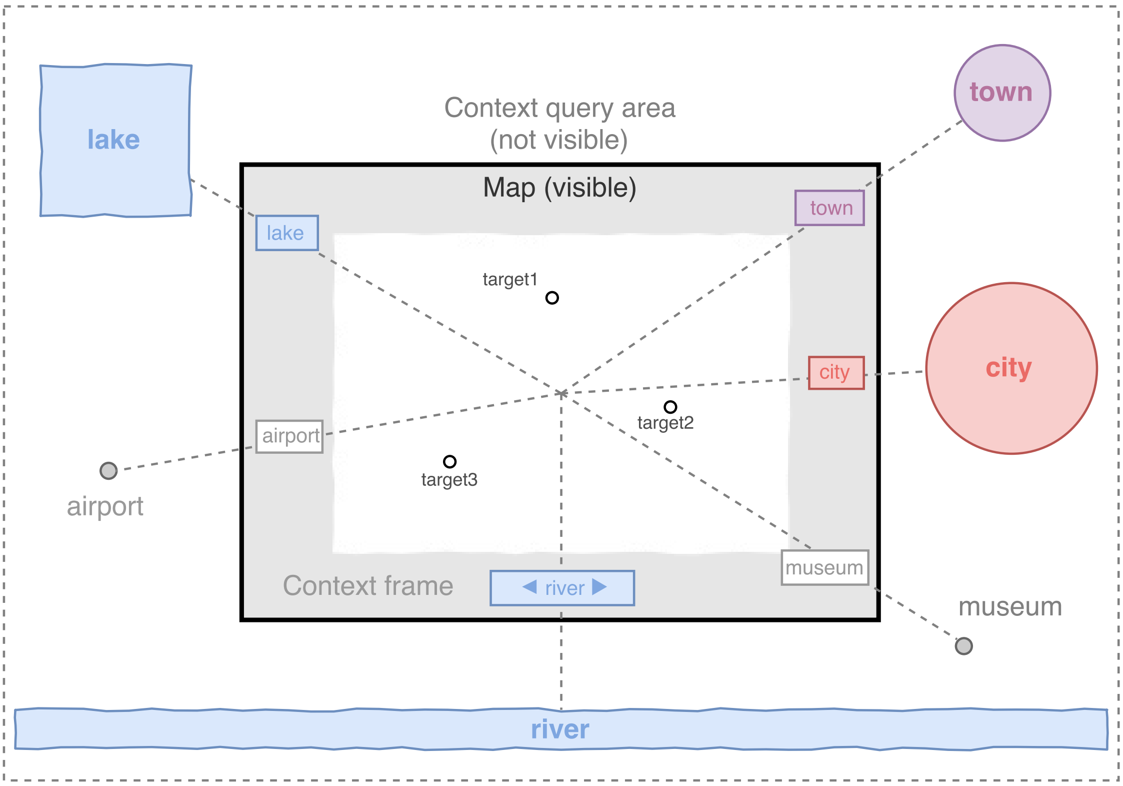

Figure 2: A schematic overview of the context frame, showing the map with some targets of interest (e.g. *target1*, *target2*, and *target3*), the context query area, and a set of notable objects. The notable objects must be contained in the context query area (not visible to the user), but not in the map (visible to the user). Depending on the scale, notable objects can be represented as points (e.g. airport and museum), as polygons (lake, city and town), and as polylines (river).

map, similar to the ones proposed in this article, have been used before in paper maps, for example in tourist maps to indicate nearby points of interest (e.g. a labelled arrow stating "2 km to the Colosseum"). They are also commonly used in satellite navigation systems to point to the destination of the current trip, such as the blue arrow in Google Maps (Jakobson & Rueben 2013).

The margins of the map provide a liminal space between what is mapped and what is not, where contextual information can be placed. Unsurprisingly, map margins have been used by cartographers throughout the history of the medium. Cartographic marginalia can embed contextual information about the map content, such as scale bars, attribution, legend, and grid coordinates. Decorative marginalia, very popular in pre-20th century maps, convey useful information about the cartographer's intentions and values, hence providing insights to historians.[2] Writing at the dawn of web mapping, Suzette Miller (1999) classifies elements at the margin of digital maps as *spatial marginalia* (scale bars, scale, and North arrow), *manipulaton marginalia* (panning and zooming buttons), and *navigation marginalia* (title, coverage, and time frame). All these marginalia purport to provide spatial, temporal, and thematic context to the map user.

While panning and zooming remain central operations with maps (You et al. 2007), interactive cartography has recently converged to two dominant models: (i) mouse to pan and mouse wheel or buttons to zoom, and (ii) touch interfaces, in which panning can be performed with one finger and zooming with a pinch gesture. Without belittling the achievements of ubiquitous, web-based and smartphone-based cartography (Gartner et al. 2007), it can be argued that the problem of the lack of context has worsened in the last decade. The possibility of rapid movements on the map and constrained screen sizes result in frequent disorientation, where small portions of the planet are presented to users without appropriate contextual cues. The context map frame discussed in this article aims at mitigating this old problem. To the best of my knowledge, no example comparable to the proposed approach can be found in commercial mapping systems and in research projects.

Algorithm 1: Selection and ranking of notable objects

Data: Map bounds B; zoom level z; set of geographic objects G, expansion factor e; set of weighting functions f for properties of G objects; weight W_d for distance and W_p properties; shrinking factor x; minimum collision distance m;
Result: Relevance ranking of spatial objects R_G; Set of spatial cues C;

```
// init
query area bounds Q ← expand bounds B by factor e^z;
selected objects G_S ← find G objects (intersect ∨ within Q)
  ∧¬ (intersect ∨ within B);
// calculate object attributes
for obj ∈ G_S do
    d_obj ← object distance from map centre;
    for property p ∈ obj do
        p_obj ← apply weighting function f_p;
// rank objects
for obj ∈ G_S do
    r_d ← rank obj by decreasing distance d_obj;
    for property p ∈ obj do
        r_p ← rank obj by increasing p_obj;
    obj overall rank r ← weighted combination of r_d and
      all r_p using W_d and W_p;
// place spatial cues
context frame bounds F ← reduce B by factor x;
set of cues C ← ∅;
for obj ∈ G_S sorted by r do
    line l ← trace line between obj and map centre;
    loc_c ← find intersection between F and l;
    for cue c ∈ C do
        if distance (loc_c, c) > m then
            c_obj ← new cue for obj at loc_c;
            add cue c_obj to C;
```

3 Computing the context frame

The context frame aims at supporting the positioning of the map content relative to known geographical objects. To enable a smoother relative positioning, this framework is designed to select and display *spatial cues* around the map, reducing the need for zooming and panning operations. An overview of the framework is depicted in Figure 2, showing the visible and non-visible parts of the geographic space.

In order to operationalize this idea, the framework needs a strategy for the selection of *notable objects*. Notable objects conceptually overlap with landmarks, and must be known to the user as spatial anchors (Caduff & Timpf 2008). Unlike landmarks, however, the purpose of these objects is to support map interpretation and interaction, and not wayfinding. Depending on the application domain, notable objects can include diverse geographic features at different scales, such as cities, buildings, and airports, as well as political entities. Using geographic information retrieval (GIR) principles, it is possible to estimate the relevance of objects (De Sabbata & Reichenbacher 2012).

The approach starts by selecting all notable objects falling within a query area and not within the map bounds. The objects are then ranked from the most to the least salient, based on a set of properties, such as distance from the map centre and object properties (e.g. object area, city population, or airport passengers). These aspects are combined into a single ranking, prioritising different facets based on weights. The system starts to place a spatial cue in the context frame for each object, avoiding collisions. Collisions are detected when two cues are closer than a minimum distance between cues, expressed in screen pixels. Graphically, the spatial cue includes a line that indicates the specific direction from the map to the notable object. The computation stops once the context frame is filled.

The computation is outlined in Algorithm 1. The spatial extent of objects can be represented as points, polylines, and polygons. The zoom level is that of typical web maps ($z \in [1, 18]$), and is conceptually equivalent to map scale. Experimentally, a suitable expansion factor was identified as $e = 1.4$. The weights are used to increase or decrease the relative importance of distance and

[2] https://web.archive.org/web/20170309065423/https://www.chazen.wisc.edu/images/uploads/Files/Marginalia_in_cARTography_F.pdf

Figure 3: Context frame around Avigliana, in North-Western Italy, showing cities with the country code. The selection combines city distance and population ($w_d = .8$, $w_p = .2$). When clicking on a contextual cue, the map pans to it. Sources: Leaflet (map), ESRI (map tiles).

properties ($W_d + \sum W_p = 1$). The line l is traced between the centre of the map and the closest point belonging to the object. A suitable shrinking factor to calculate the context frame bounds is $x = .8$. Finally, 80 pixels was found to be an appropriate minimum distance m.

4 An Italian case study

To illustrate the functioning of the framework, this section presents a case study on real-world data, based on the relative positioning example in Figure 1. The set of input geographic objects include cities with more than 30,000 inhabitants,[3] represented as points, and countries, represented as polygons.[4] The computation was carried out with the web prototype. The ranking of the notable objects was controlled by three parameters: (1) geodesic distance from the map centre, (2) population for cities, and (3) area for countries.

Table 1 shows the top-ranked objects based on these parameters, showing the difference between individual parameters and their combination. Empirically, the most meaningful results are obtained with a combination of distance and the other parameter: Distance alone prioritises close objects that might be too small to be known, while population and area alone tend to prioritise known objects that might be very far. An instance of the context frame in the user interface is shown in Figure 3, with cities as input objects. The spatial cues include geodesic distance in km. In this instance, meaningful results occur when distance is prioritised over population ($w_d = .8$, $w_p = .2$).

[3] Source: https://simplemaps.com/data/world-cities
[4] Source: https://github.com/johan/world.geo.json

5 Conclusion and outlook

This article outlined a generic framework to select and present spatial cues to map users. This approach supports map usage, reducing the need for zooming operations for relative positioning. Future research will focus on formal evaluations of the approach, relying on user testing to identify design limitations and possible improvements in the algorithm and user interface. Several tasks and use cases can be explored to ascertain to what extent the context frame supports users in the interpretation of the geographic content of the map, also exploiting visual variables that are fixed in the current version, such as cue colour and size.

The selection of notable objects is indeed an application- and task-dependent operation, and more case studies are needed to identify optimal parameters for the core algorithm. While the parameter values in the case study appear to perform reasonably well, a systematic evaluation is needed to provide scientific grounding. The ranking process will be evaluated with different combinations of parameter weights. Testing of algorithm variants is needed to ascertain which parameters look more promising across geographical locations. Different, richer input datasets can be harvested through APIs to identify potential notable objects, such as Wikipedia and GeoNames.

Beyond the interaction design aspects of the framework, a strand of research on spatial cues concerns their cognitive implications for users. As wayfinding becomes increasingly machine-led, reducing the active cognition of surroundings, it is worth designing technologies that support, and do not replace, spatial cognition and learning (Münzer et al. 2012). Several research questions come to mind about the map context

Type & *param.*	Top 10 notable objects
Cities *Distance*	Turin IT, Asti IT, Aosta IT, Novara IT, Sion CH, Grenoble FR, Annecy FR, Genoa IT, Milan IT, Monaco MC
Cities *Population*	Milan IT, Turin IT, Marseille FR, Lyon FR, Florence IT, Zurich CH, Geneva CH, Toulouse FR, Nice Fr, Genoa IT
Cities *Dist.+pop.*	Turin IT, Milan IT, Genoa IT, Nice FR, Geneva FR, Grenoble FR, Lyon FR, Marseille FR, Lausanne CH, Como IT
Countries *Distance*	France, Switzerland, Austria, Germany, Spain, Slovenia, Luxembourg, Belgium, Croatia, Czech Republic
Countries *Area*	Turkey, Ukraine, France, Spain, Germany, Poland, United Kingdom, Romania, Belarus, Tunisia
Countries *Dist.+area*	France, Spain, Germany, Austria, Poland, United Kingdom, Switzerland, Czech Republic, Ukraine, Tunisia

Table 1: An example of variants of selection of notable objects. The target area is Avigliana, located in North-Western Italy, with equal weighting between feature distance and properties ($w_d = .5$, $w_p = .5$).

frame. Do users acquire more configural knowledge about the geographic space with or without the context frame? What are the effects of different weights on the parameters? Are some types of notable objects more effective in spatial learning? In this cognitive direction, personalization (Ballatore & Bertolotto 2015) is likely to improve the effectiveness of the context frame, weighing the prominence of notable objects based on individual preferences.

Acknowledgements. I wish to thank Gavin McArdle (University College Dublin) for his feedback on a very early iteration of this idea. The web prototype was built on a number of resources, including the Leaflet JavaScript library (and derived libraries), map tiles from ESRI, and open datasets about countries and cities from https://github.com/johan/world.geo.json and https://simplemaps.com/data/world-cities.

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