Towards automatically generating maps for wayfinding and orientation

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Abstract

People easily get lost when their navigation support systems malfunction. Previous research has focussed on enriching route descriptions with salient features, or developing methods to better visualize distant features on small screen devices in order to support spatial knowledge acquisition. In this paper we investigate the question, which features users prefer to have displayed on the map in order to orient in the environment and find their way along the route. We automatically generate maps by manipulating their information content for different routes and for different sections along the routes. We empirically investigate which of these maps are preferred. We found that there are larger differences in users' preferences between the sections within the same routes, than there are between conceptually similar sections between different routes. These results enable us to focus in future on specifying rules to select orientation information for conceptually different map sections and different routes, and, further on, opens the possibility to automatically generate maps for wayfinding and orientation.

Keywords: Spatial knowledge acquisition, wayfinding, navigation, orientation

1 Introduction

Navigation support systems are designed to support path guidance and finding a destination. However, when offloading part of their cognitive processing in wayfinding, people easily get lost when the devices malfunction. One of the reasons is the fact that the displayed information content is mostly based on Level of Detail (Clark 1976), and because of the small device screens, spatial knowledge acquisition requires a lot of user interaction, like zooming and panning.

Previous work has tackled separate aspects of how spatial knowledge acquisition can be supported and how the required information can be automatically generated. It was shown that people include landmarks in route instructions, both at decision points and along the route (Denis 1997; Daniel & Denis 1998; Lovelace et al. 1999). Moreover, people include not only local, but also global landmarks to support global orientation (Schwering et al. 2013; Anacta et al. 2016; Schwering et al. 2017). Münzer et al. (2012) have shown that wayfinding support systems can either support wayfinding, by presenting the regions around decision points, or configurational learning, by presenting comprehensive configural information.

There have been several attempts to computationally enrich wayfinding instructions with landmarks (Raubal & Winter 2002; Nothegger et al. 2004; Duckham et al. 2010), however little attempts towards identifying only relevant information for spatial knowledge acquisition. Richter et al. (2005) presented an approach to automatically generate abstract route descriptions, which are adapted to the characteristics of the route and the environment. They, however, focus on the representation instead of the selections of information. Schmid et al. (2010) presented an approach to algorithmically generate route aware maps by considering regions to structure the environment. We argue that in order to successfully support orientation, map visualizations must display only relevant entities of all types of map features.

In this work, we investigate the suitability of map variations, which differ in the amount of information content to support orientation in the environment and guidance along the route. Therefore, we select several map sections for different routes and different parts of the routes and automatically generate maps for these sections. We select the conceptually similar map sections for different routes based on the following criteria: (1) the part of the route that is selected; (2) the map scale of the particular map section. We hypothesize that the suitability of the maps, in terms of supporting orientation in the environment and supporting path guidance, varies stronger across conceptually different sections within the same route, than between conceptually similar sections across different routes. We empirically test this within a pilot study.

2 Method

We randomly select two routes within North Rhine-Westphalia, a state in Germany, with an approximate Euclidean distance of 10 km between start and destination. Within each route we select four conceptually different sections, which are the same for both routes (see Figure 1 and Figure 2): Section 1 displays the start of the route in a large map scale; Section 2 displays the start of the route in a smaller map scale; Section 3 displays an intermediate part of the route in a smaller map scale; Section 4 displays the end of the route in a large map scale.

For all eight sections, we automatically generate different maps by varying their map content (Table 1). We select three different categories of map features, which are (1) structural regions, where we distinguish between urban and rural areas, (2) the overall street network, which considers the whole street network of the map, and (3) the specific street network, which only considers the street network around the route. We refer to the latter as depth, which relates to the algorithm that selects connecting streets up to a specified depth from the route.

Figure 1: Overview of route 1 with an indication of the selected sections.

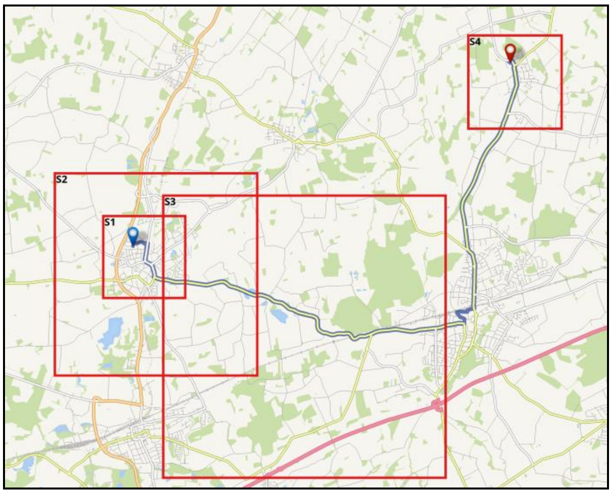
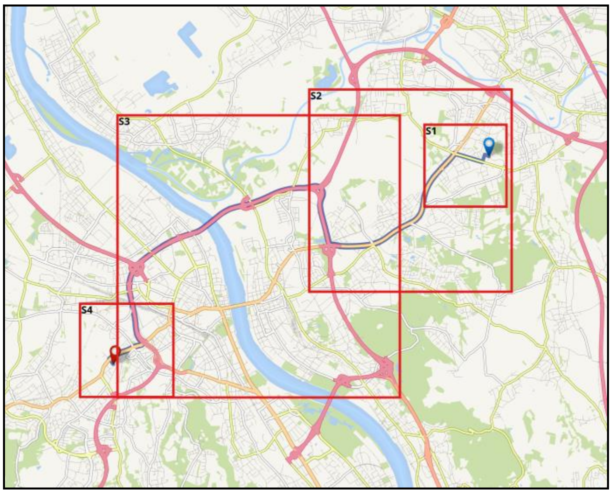


Figure 2: Overview of route 2 with an indication of the selected sections.



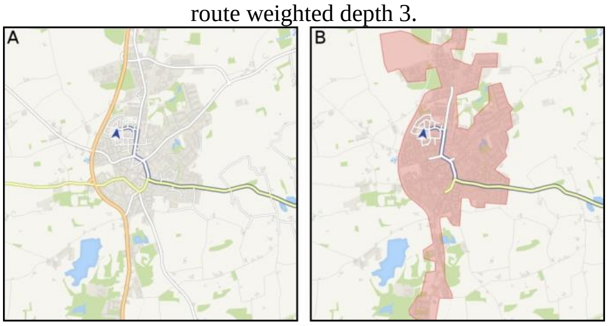
We systematically vary the map content along these categories. For the structural regions, we distinguish between the attributes no indication of urban areas (further on as no region), and indication of urban areas (region). For the network, we distinguish between the attributes no indication of overall network (no network), indication of the network skeleton (network skeleton), and indication of the whole network (full network). We define the network skeleton as the street network consisting only of the main streets of the environment shown on the map, without smaller streets, especially residential streets. For the route depth we distinguish between the attributes indication of no network (route depth 0), indication of network up to depth 3 (route depth 3), and indication of network up to depth 3 constrained to the same or higher street class with respect to the connecting route segment (route weighted depth 3), such as only selecting secondary of higher class streets around secondary class route segments.

Table 1: Categories and Attributes of the varying map content.

Categories	Attributes
region	region
	no region
network	no network
	network skeleton
	full network
depth	route depth 0
	route depth 3
	route weighted depth 3

Although the underlying environments differ for the two routes, we nevertheless expect that there are smaller differences in the users' selections between conceptually similar sections across the two routes, than there are between the four conceptually different sections within the two routes, respectively.

Figure 3: Example map sections showing different map content for the three specified categories. (A): no region – network skeleton– route depth 3; (B) region – no network – route weighted depth 3.



2.1 User study

We conducted an experiment, to investigate the differences between conceptually similar sections across different routes, and across different sections within the same route. We ran a pilot study with nine participants (3 males, 6 females; mean(sd) age: 25.6(3.4) years), who were compensated for their participation. Each participant specified their preferences for all four selected sections for both routes (4x2 within-participant design). The participants were asked to imagine sitting in a car at the indicated position having to navigate the route. After filling the Spatial Strategies Questionnaire (Münzer & Hölscher 2011), participants were asked to select their preferred map. They were instructed to choose a map, which will help them best to orient in the environment and navigate along the route. They were assigned to the routes in a pseudo-random order and had to specify their preference for all four sections of the routes by picking one of its possible variations. All possible variations were presented simultaneously on the screen, and map sections were presented one at a time, from start to the destination. At any point, participants were allowed to revise their selection. At the end of each route, participants were shown their selections for the particular route and allowed to go back and revise their selection.

3 Results

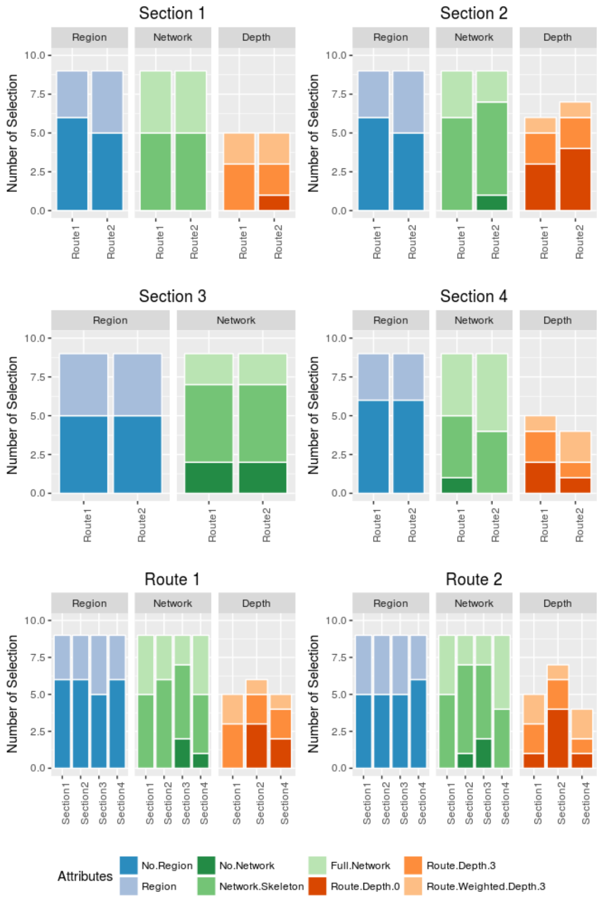
We analyzed the differences in participants' selections by first aggregating how often each attribute for each category was chosen for the particular map section. From the plots in Figure 4, it can be seen that a similar number of participants prefer the indication of urban areas and no indication of the urban areas. For the network category, it can be seen that only a few participants prefer to see no overall network, whereas most participants prefer to see the network skeleton. For Section 1 and Section 4 approximately half of the participants prefer to see the full street network on the map. For the depth category, there is no clear preference in the participants' selection, except that more participants seem to prefer no specific network around the route for Section 2.

We calculated how the number of selections differs between the two routes (Figure 4: Section 1 to Sections 4) and between the four sections (Figure 4: Route 1 and Route 2). For the differences between the two routes (Figure 4: Section 1 to Section 4), we calculated the absolute difference between the two values within each of the three categories Region, Network, and Depth. For the differences between the four sections (Figure 4: Route 1 and Route 2) we calculated the mean absolute difference between the values within the three categories Region, Network, and Depth. For testing the hypothesis, we ran a two-sample t-test. Thereby, we compare the differences in the users' selections between the two routes to the differences in the users' selections between the four sections. The results of the t-test shows that there are significantly larger differences in users' selections between the four conceptually different sections within the two routes (mean = 1.05), than there are between conceptually similar sections between the two routes (mean = 0.48): $t(24) = -2.8$, $p = 0.009$.

4 Discussion and Outlook

From the plots, we saw that there seems to be a higher preference for the full network for Section 1 and Section 4 for both routes. Because of the small sample size, this difference is not significant. We, nevertheless, argue that there might be a difference due to the different scales of map sections. Participants in our experiment prefer maps with less information for smaller scales, because less information might be sufficient to orient in the environment and navigate along the route. Also for the specific street network, participants seem to prefer less information around the route for smaller map scales (see Figure 4, Section 2, depth category). These results are in line with cartographic techniques, where the amount of displayed information on digital maps is reduced with a decreasing map scale (Level of Detail), in order to keep the map readable and not overloaded with too much detailed information. In contrast to cartography, where one Level of Detail is applied to a map section of a certain map scale, we aim to automatically generate maps with varying amount of details, depending on the users' route context, the conceptually different sections of a route, and the features' relevance for orientation.

Figure 4: Number of Selections by Category (Region, Network, Depth). The plots distinguish, on the one hand, different Sections (1 to 4) for the two different routes, and, on the other hand, different Routes (1 and 2) for the four different sections of each route



We hypothesized that there are differences in the suitability of different maps to support orientation in the environment and path guidance along the route. We expected that there are larger differences between conceptually different sections within the same route, than there are between conceptually similar sections across different routes. Our findings confirm that there are significantly larger differences between the different sections within the same route, than there are between conceptually similar sections between different routes. This confirms that our identification of conceptually similar map sections across different routes is reasonable. Although the environments of the two routes are structured very differently – the route in Figure 1 goes between two villages in a rural area, whereas the route in Figure 2 is located in a more populated area of a city and even goes via a highway – there are still little differences in peoples' selections between conceptually similar map sections across the two routes. As we tested routes of a specific length (approx. Euclidean distance of 10 km), we would expect that the result might be different for different route lengths. This will be further investigated in future studies.

The larger differences between different sections within the same routes may also confirm the previous suggestion that the differences are caused by the different map scales, which are varied within the two routes. Another possible explanation for the differences between the map sections could be a correlation with the number and location of decision points within the particular map sections. This, however, requires further investigations in future work.

Implications of our work are the possibility to adhere to our concept of specifying conceptually similar or different sections for different routes, which gives us the possibility to further investigate how these sections differ in terms of environmental information that supports spatial knowledge acquisition and orientation. In future work, we aim to further specify selection rules for relevant orientation information, and develop an algorithm to automatically generate maps for wayfinding and orientation.

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