Wayfinding Through Orientation: Schematizing Landmark, Route and Survey Information in a Single Map

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Abstract— **Dominant approaches in computer-assisted wayfinding support adhere to the deeply problematic principles of turn-by-turn navigation. We suggest a new approach called "Wayfinding Through Orientation" which supports the acquisition of spatial knowledge and cognitive mapping for advancing the user's spatial orientation. To visualize instructions of orientation navigation systems, we suggest to (i) select relevant landmark, route and survey information and (ii) visualize this information in schematic maps. The schematization faces two challenges: First, the schematization of routes might conflict with the schematization of survey information (e.g. a street network). Second, point-like or regional landmarks need to be placed topologically correct w.r.t. the survey information, but also in a correct spatial relation w.r.t. the route.**

Keywords: network schematization, route schematization, navigation, orientation information

I. Motivation and Problem Description

Wayfinding is a task that we conduct every day while going to work, visiting friends, or going on vacation. With the emergence of consumer-grade car and pedestrian navigation systems, we gained omnipresent support for wayfinding tasks in unfamiliar environments. Although this technology has gone through tremendous development, with cognitive aspects attracting particular interest, it still suffers from some fundamental shortcomings: State-of-the-art wayfinding support follows the principles of turn-by-turn navigation. It guides users towards the destination by giving them direction instructions at each decision point one after another. With turn-by-turn navigation, users can reach the destination on the best (e.g. fastest, simplest, easiest, safest) way; however, they might have no broader orientation and no survey-like knowledge about the environment and the route at all. Turn-by-turn instructions are incompatible with the naturally employed ways of processing spatial information as well as the forms in which we communicate it to others. People do not execute instructions separately, one after another, but integrate the information, spontaneously memorize salient features like landmarks as well as aspects of the spatial configuration during wayfinding, and build up cognitive maps to orient themselves in their environments. Because turn-by-turn navigation solely communicates directions at decision points, it only supports users in the acquisition of route knowledge, but not in the users' spontaneous ability to gain orientation in unfamiliar environments (Fig 1).

The detrimental effect on spatial learning of nowadays turn-by-turn navigation systems was shown in several empirical studies: Münzer [1, 2] compared computer-assisted navigation to traditional map-based navigation and found differences in incidental knowledge acquisition. Users of navigation systems showed good route memory but bad survey knowledge. Ishikawa et al. [3] investigated how turn-by-turn navigation with different tools affect the acquisition of survey knowledge. They compared navigation with GPS devices to navigation with paper maps and to the direct experience, finding empirical evidence that users travelling with GPS devices acquire less survey knowledge. Münzer et al. [2] examined the effect of different visualization modes on incidental route and survey knowledge acquisition during an assisted tour through a real environment. When wayfinding instructions were presented in a 'guidance mode' (turn-by-turn instructions from the egocentric perspective), then route memory was strengthened at the cost of survey knowledge. Schmid et al. [4] developed a (non-schematic) map that provides local and global orientation and showed that it has a positive effect on speed and accuracy during a self-localization task. They did not investigate survey knowledge acquisition.

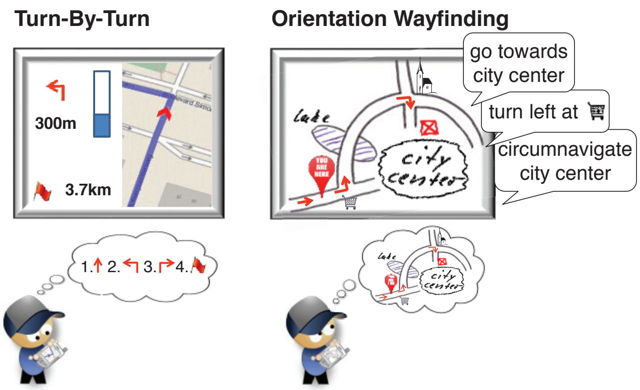

Fig. 1. Turn-by-turn wayfinding gives direction instructions at decision points supporting users in the acquisition of route knowledge, while orientation wayfinding uses orientation information supporting users to build up a cognitive map.

We suggest a new approach called “Wayfinding Through Orientation” [5, 6] which supports the acquisition of spatial knowledge and cognitive mapping for advancing the users’ spatial orientation. Being oriented on one’s way is a prerequisite to enabling people to verify instructions and to incorporate new spatial information into their existing knowledge structure. The goal of orientation navigation systems is to communicate route information in a way that enables users to build up a cognitive map of their environment while navigating. They use this cognitive map to orient themselves on the route and in the surrounding environment.

II. Wayfinding Through Orientation – The Paradigm

The key to foster orientation and cognitive map making lies in the information the user receives during navigation. Therefore our research is guided by two questions:

Research Question 1: Which spatial information fosters orientation and therefore needs to be presented in the navigation system?

We believe that orientation navigation systems need to communicate three important types of spatial information that you can find in cognitive maps:

- Landmark information: information about discrete objects or scenes that differ from the surroundings. Landmarks (point-like or regional) can be used as anchor points for structuring and integrating spatial information.
- Route information, i.e. information about sequences of route segments and the turning angles between route segments, including the sequence of landmarks along the route.
- Survey information, i.e. map-like representation of metric spatial relationships between non-linearly-aligned environmental features

Research Question 2: We need visualizations that highlight the key features in each of these three categories (landmark, route and survey information).

Current visualizations of navigation systems use standard topographic maps and highlight the route on the map. To get optimal support at the decision points, the navigation system zooms into the map showing a small area round the decision point with all alternative streets. We believe that schematization is a promising way to create a visualization that shows a larger area of the map *and* gives detailed information about the decision point at the same time. However, the challenge of map schematization is that all three types of information – landmark, route and survey information – need to be schematized at the same time, although the schematization of survey features (e.g. street network) might conflict with the schematization of the route.

III. Related Work

A. *Type of Information Provided by Navigation Systems*

There exist many different navigation assistance systems providing different types of information. Fig 2 gives an overview of spatial information communicated by different navigation systems.

Fig. 2. Different visualizations of navigation assistance systems, classified according to the type of information they provide [1].

Navigation assistance system 1 (the left-most) provides survey information in the form of a digital map. Usually the device can localize the user e.g. via the GPS and show their current position on the map. However, such a system does not have the information about the destination (as this might be unknown) and thus does not show the route to the destination.

Navigation assistance system 2 provides information about the destination and tells the user in which direction they can find the destination based on their current position. No additional route or survey information is provided. This scenario occurs for example when a user is hiking in the wild and no map or predefined paths exist. Another example for this application is a car-finding-app, in which a user can localize their car with GPS coordinates and the app will show the direction and distance to the car without a digital map (e.g. on a large airport car park).

Navigation assistance system 3 provides survey information in the form of a digital map and destination information as a location on the map. Sometimes the device shows the position of the user on the map as well, but it does not offer a route planning function, thus the task of finding the route is up to the user. In practice, this is how users of mobile mapping apps often interact with them in an ad-hoc context: comparing the You-Are-Here indicator with the location of the desired destination (e.g. a nearby cafe) can be sufficient to adjust one's trajectory on-foot few hundred meters away from the destination, without using the app's routing algorithm.

The two navigation assistance systems 4a and 4b provide route and destination information. System 4a visualizes only the route and the destination, while system 4b shows also the background digital map. However, due to the tradeoff between scales and levels of detail, this visualization is not suitable to communicate overview and detailed information both at the same time. As a consequence, the survey information communicated is very limited (thus we classify it as “not provided”). The user can zoom out to obtain more survey information, however, the information about the route then becomes too small to be useful for navigation. This approach does not facilitate the acquisition of route knowledge and survey knowledge in an integrated manner. System 4b represents today’s car navigation systems: Based on the destination information and the current position, it calculates the route and shows the relevant route information for the next decision point.

Navigation assistance based on “wayfinding for orientation” would provide destination, route and survey information in a way that is easily perceptible by the user. Such a system does not exist at the moment. Fig 1 right side shows what it could potentially look like.

B. Visualization in a Schmematized Map

Schematized maps omit details by selecting features and highlighting them and particular spatial relations even if this does not reflect exactly the original geometry. Usually, schematization algorithms are either optimized for visualizing one-dimensional structures such as routes, or for visualizing 2-dimensional layout such as a network of different metro lines.

In the last two decades, generalization techniques have been proposed for the specific challenge of the automatic drawing of schematic maps. Inspired by handmade route sketch maps, Agrawala and Stolte [7] proposed a schematization method for driving routes. The ideal simplified layout is found by a simulated annealing algorithm strategy that takes into account relevant decision points, like highway ramps, to be more faithful to the original shape. Also for the purpose of driving routes, Delling et al [8] presented mixed-integer-programing to solve this problem. Those are examples of schematizations aimed for route schematization.

Other publications presented methods for the schematization of networks. The automatic metro map layout problem [9] gained the attention of researchers in the last decade, and the diversity of methods applied in this schematization process is abundant [10]. Although the metro map layout has a different practical application, some of its principles, as listed by Li [11], can be adopted to orientation maps as well. However, to the best of our knowledge, no approach exists that combines route schematization for the purpose of driving with network schematization, and includes landmark features to highlight important locations.

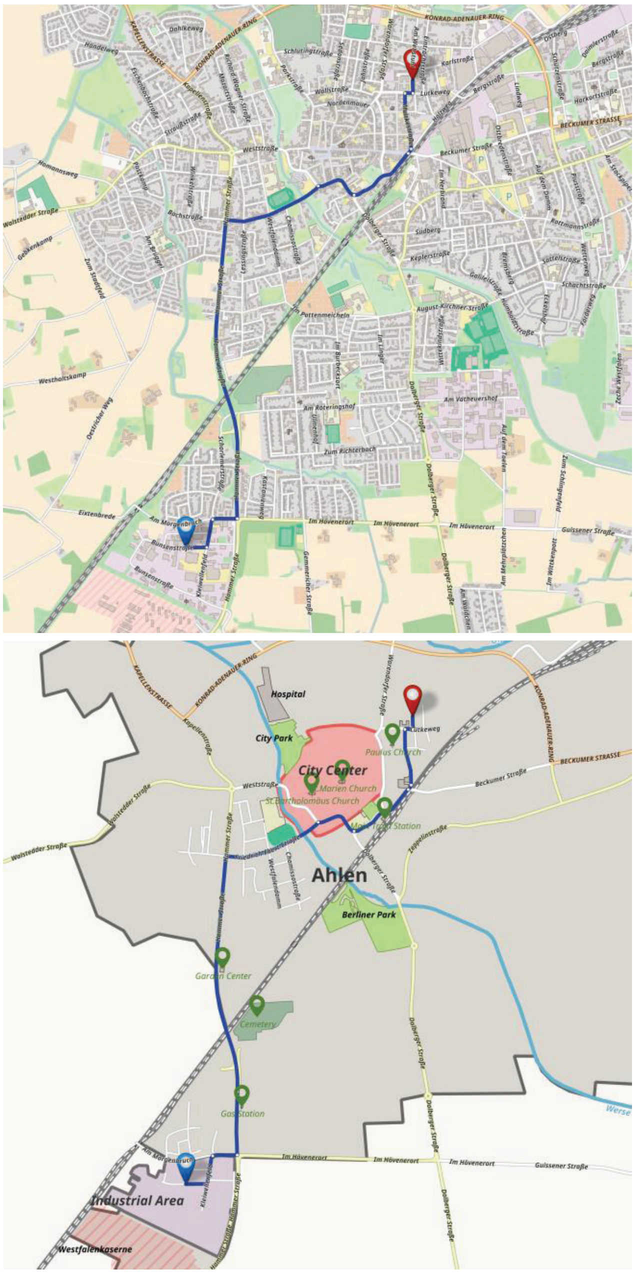

Fig. 3. Left: Original data material for a route (based on OpenStreetMap). Right: Orientation map with orientation information highlighting different regions such as an industrial area and the city center, landmarks such as a gas station, and important streets within the environment and for this particular route.

IV. Which Information Creates Orientation?

In various experiments [6, 12, 13] we explored the potential of different types of information for incidental spatial knowledge acquisition, as we believe that a cognitive map improves orientation during navigation. Besides the route information (which is obviously relevant in a navigation scenario), we identified landmarks, network structures, and structural regions as relevant features that should be included into orientation maps. Landmarks are defined as “geographic objects that structure human mental representations of space” [14, p. 7], thus any object might serve as a landmark. The network structure is considered as the relevant streets network in addition to the route, which is assumed to support orientation. For the structural regions, we distinguish administrative regions and environmental regions. The following figure shows on the left a route highlighted in a topographic map in a traditional navigation system and on the right an orientation map with a largely reduced number of features. More details on which information should be selected for orientation is given in [13].

For the schematization we need to distinguish the role of the features of an orientation map, e.g. whether they are on-route or off-route (local versus global landmarks) and their location (e.g. at decision points). The generalizations in the schematic layout need to be applied to enable incidental spatial knowledge acquisition.

V. HOW TO VISUALIZE ORIENTATION INFORMATION?

As described above, we are aiming for a visualization that can schematize at the same time the route, landmarks, and the surrounding street network.

- The route together with its side streets at decision points as well as non-decision points, which should be visualized in a simplified way with few bends. Angles of main turns and crossing streets should have a low level of granularity to facilitate their interpretation e.g. according Klippel’s wayfinding choremes [15]. Moreover, sections of the route with high concentration of decision points need to be adequately visualized.
- On-route landmarks: here we need to pay particular attention to the spatial relation a landmark has w.r.t. the route, e.g. the simplified shape of the landmark and the route have to reflect whether a route passes / goes around / crosses this landmark. We also need to distinguish landmarks according to their dimensionality into point-like, linear and regional landmarks, which are handled differently in the schematization.
- Off-route landmarks: they are global landmarks and are used as references for orientation and survey knowledge acquisition. Here, the topological correctness seems to be more important than reflecting the spatial relation of the street network to the landmark. Like before, the dimensionality influences the schematization.
- The surrounding street network has to be schematized as well. In addition to criteria from metro map schematization, where routes are simplified through bend minimization, octolinearity, etc., we also need to consider the general structure of a city. The street network schematization of a city with a star- or ring-like structure, for example, should also reflect this.

Our first attempts of schematizing all orientation features in one map balancing the different requirements are shown in Figs. 4 and 5.

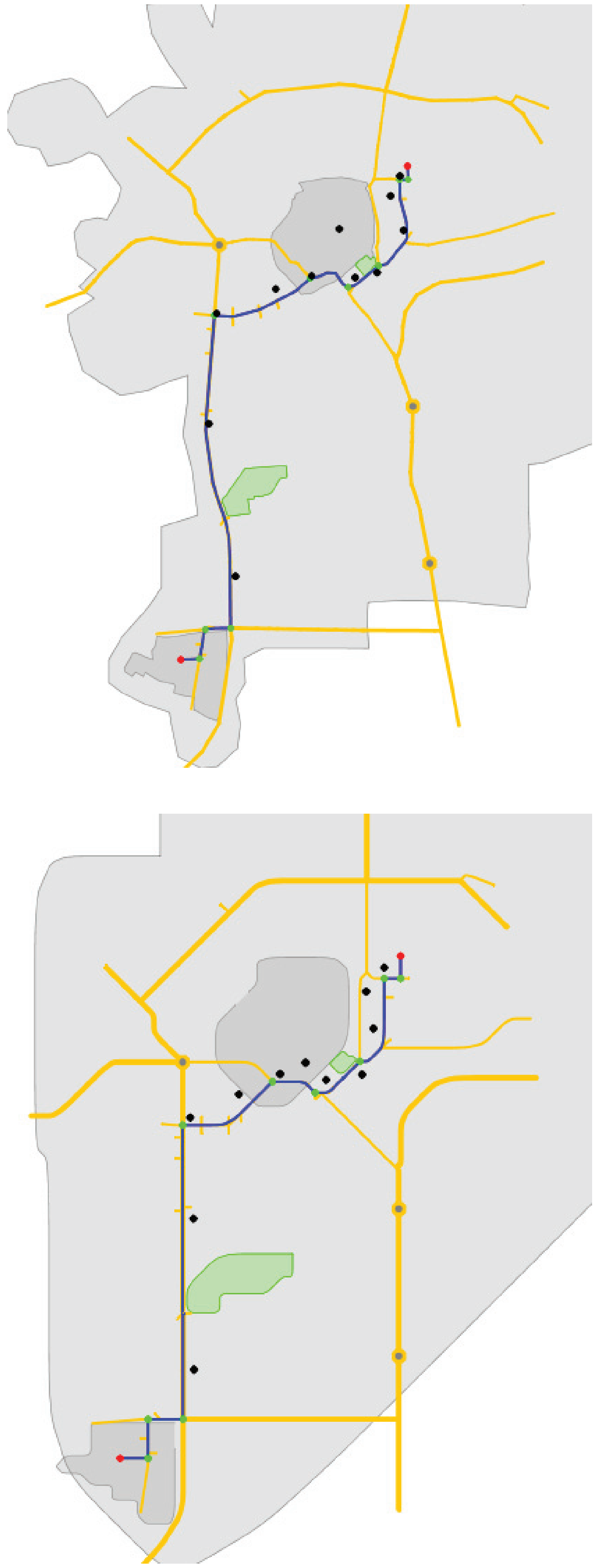

Fig. 4. Schematization of a route within a city and thus, with a relatively large surrounding street network. Top: Non-schematized map. Bottom: Schematized map with polygonal landmark in a street network (algorithm still under development). The challenge is to preserve topological and spatial relations between all features during schematization. The yellow streets highlight the surrounding street network. The schematization includes a lake (in blue), the administrative region (grey in the background), the city center (dark grey) and a park (green).

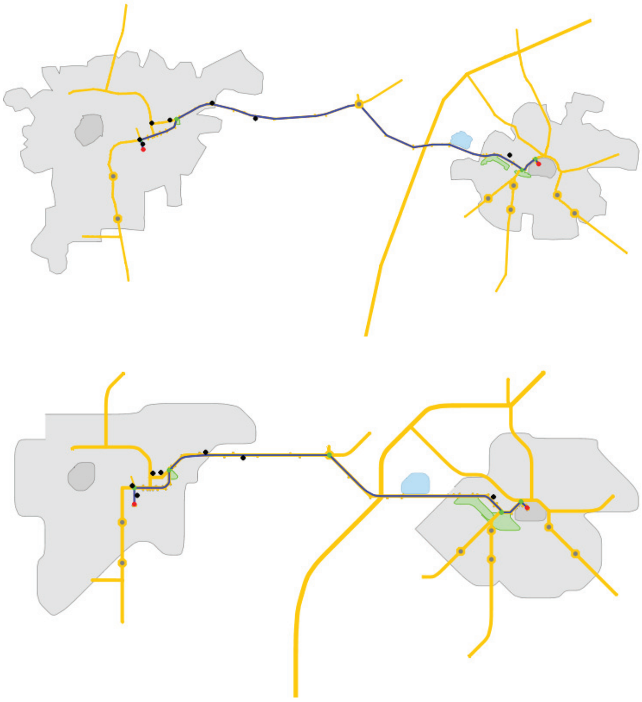

Fig. 5. Schematization of a route between two cities: context features (regional landmarks and street network) are mostly along the route (Top: non-schematized route, bottom: schematized route).

VI. Conclusion and Future Work

In this paper we suggest that navigation systems should communicate orientation information as well as route instructions in a schematic map to improve incidental spatial learning, cognitive map making, and orientation of people while travelling with a navigation system. To date there exist route schematization approaches that simplify the layout of the route by minimizing bends, highlighting wayfinding information at decision points, etc. They usually do not include additional information such as regional landmarks along the route. Network schematization approaches such as metro map schematizations do not focus on a single route but on a network optimizing the layout for travels from any node in the network to any other node. In contrast, we aim for a schematic map that schematizes route *and* orientation information at the same time: The schematized route should highlight wayfinding information at decision points, but also the relations to regional landmarks along the route and to surrounding off-route features. These surrounding off-route features – the orientation information – are global point-like or regional landmarks and the street network. The off-route features are not visualized for navigation but for orientation, i.e. in particular the goals for network schematization differ from traditional metro map schematization: Our schematization aims to highlight the layout of an environment providing a spatial structure to the map rather than supporting navigation tasks through the street network.

In this paper, we suggest a set of features such maps should contain and outline the problems of schematizing landmark information, route information and survey information at the same time. After having developed such an approach, we need to evaluate whether schematic orientation maps actually lead to an oriented navigation. The quality of our orientation maps are not just evaluated based on drawing rules. We also aim to evaluate the degree of incidental spatial learning with orientation maps versus other maps, the speed of recognizing important information and the navigation performance in simulated wayfinding tasks.

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