Functional Scales in Assisted Wayfinding

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Abstract

GPS-based navigation systems are widely used to get wayfinding assistance. Current navigation systems incorporate different map scales for presenting wayfinding instructions, however, the selection of scale is not supported by psychological findings. Different tasks of the users such as the identification of the next decision point or the orientation within the environment might be supported best at particular scales. We propose a new conceptual distinction of *functional* scales with respect to their role in supporting wayfinding and orientation. We suggest that these *functional* scales can have a benefit for supporting wayfinding and orientation if used for providing wayfinding instructions. This we aim to empirically evaluate in future work.

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1 Introduction

Current navigation systems incorporate different map scales for presenting wayfinding instructions to the users. Typically users may see an overview map of the whole route at the start of the travel. During the travel, the navigation system dynamically scales the map with respect to the speed of travel and the distance to the next decision point. These scale changes are very useful to support the task at hand, which is the interpretation of instruction and the identification of decision points. However, wayfinding support systems might target different task such as spatial learning and the orientation within the local or global context of the route. While the scale changes support the identification of decision points, they are not systematically chosen based on their benefit in spatial knowledge acquisition and orientation. Current research is ignoring that the relevance of environmental features for wayfinding and orientation support might depend on different goals users have during wayfinding, that are best supported at particular scales. To our knowledge, there is no work existing that conceptually distinguishes scales with respect to different functions in assisted wayfinding scenarios. In this paper we propose a conceptual distinction of *functional* scales with respect to their role in supporting wayfinding and orientation. The distinction consists of five scales that vary in the extent of navigationally-relevant space they represent.

2 Background

2.1 Environmental Features supporting Spatial Knowledge Acquisition during Assisted Wayfinding

Landmarks are important features in wayfinding and navigation, because they structure human mental representations of space [18, 2, 12]. There is empirical evidence from the analysis of human route instructions showing that these contain a significant amount of orientation information, including local and global landmarks, which support the acquisition of survey knowledge [1, 10, 9]. The feature selection, which is natural for humans, is not trivial from the computational perspective. Different approaches have been developed to automatically select environmental features such as landmarks for wayfinding and orientation support (e.g. [16, 15, 5, 3]), however empirical evidence with respect to spatial learning is rarely presented.

Others investigated users' spatial knowledge acquisition during assisted wayfinding. Different wayfinding aids such as traditional paper maps and GPS-based navigation systems were compared (e.g. [14, 7, 4]), all showing negative consequences of digital navigation systems on the formation of mental spatial representations. Navigation systems seem to change the way users attend to the environment by providing a sequential set of turn instructions that can be passively followed with little attention to the environment [6, 20, 21]. New types of instructions have been presented to support users' spatial knowledge acquisition and orientation, e.g., *spatial chunking* where elementary wayfinding actions are merged into higher order chunks that convey information about meaningful parts of the route [8]. Schwering et al. [20] suggested to provide instructions not in a turn-by-turn manner but in a holistic way in order to support spatial learning of the route as well as the surrounding environment.

Recent research has shown that the selection and accentuation of map features has a significant influence on users' spatial learning and orientation [11]. The authors described a semi-automatic process of selecting environmental features based on a classification scheme that distinguishes orientation information as landmarks, network structures, and structural regions. They showed that the accentuation of local features supported the acquisition of route knowledge, whereas the accentuation of global features supported the acquisition of survey knowledge. This research, however, neglects that the relevance of environmental features for wayfinding and orientation support might depend on the representation at different scales. Moreover, the suitability of a particular scale depends on the current situation of the driver and the task to be supported by the map visualization.

2.2 Scale

The term *scale* is used for different concepts. Cartographers use it for describing the ratio of real world distance and map distance. They specify how environmental features are represented at particular map scales. Psychologists make a qualitative distinction of *scale* with respect to the perception of space. The dominant distinction was presented by Montello who classifies psychological space into multiple classes based on the projective size of space relative to the human body [13]. He distinguished the classes *figural, vista, environmental,* and *geographical* space. Few works have looked at scales in similar contexts: Richter et al. classified the granularity of environmental features in place descriptions, distinguishing the levels *furniture, room, building, street, district, city*, and *country* [17]. Schmid et al. distinguished three levels of detail in You-Are-Here maps with respect to

Montello's psychological spaces and Worboys' nearness relations [22], which they refer to as *immediate neighborhood, larger neighborhood*, and *beyond that horizon* [19].

In the following we propose a conceptual distinction of *functional* scales with respect to their role in supporting wayfinding and orientation. Our classification is derived from the interaction of cartographic and psychological scales: Any map presented on the screen of a wayfinding support system would classify as a *figural* space in Montello's terms; however, for the purpose of supporting wayfinding, this map might represent the extent of space equivalent to either *vista, environmental*, or *geographical* psychological space (such as a turn at the current junction, or a route passing through an entire country). Seeing so different extents of space during distinct phases of an assisted wayfinding scenario is likely to affect the users' ability to spontaneously learn and orient within the environment. While the existing navigation systems utilise this principle in its most simplistic form, e.g., by displaying the route's overview at the beginning of the journey, and zooming in near junctions, this system behaviour is not optimised to continuously support spatial knowledge acquisition.

3 Functional Scales

We suggest five major categories of functional scales of wayfinding maps: *intersection, neighborhood, city, region*, and *route overview* scale. As opposed to cartographic map scales that are expressed in the ratios between real world distance and the corresponding map distance, the functional scales are defined by the containment of features relevant for different aspects of navigation. For example, one of the listed functional scales is required to contain the entire route, no matter of its euclidean length. We relate the functional scale classes to previous definitions of *map scales* and *psychological scales.* The full categorization is shown in Table 1.

The *intersection* scale depicts a particular decision point at a large scale facilitating local orientation and decision making. At this functional scale, maps contain detailed information about local features at the intersection including local landmarks and full layout of the street network. Direction instructions at decision points of contemporary navigation systems can be categorized into this scale, however, only prototypes incorporate landmarks, yet (e.g. Natural Guidance by HERE, Garmin Real Directions). We relate this category to the *vista* space (see [13]) and consider the map scale as fixed with respect to the required screen size and resolution.

The *neighborhood* scale depicts information about the local context of the route in order to support the understanding of the local route context and surrounding connections. Relevant information are considered to be local and global landmarks, the full street network, and structural regions at a size that does not exceed the particular neighborhood. Global landmarks might not be located at the route, but support the overall understanding of the neighborhood. We consider the *neighborhood* scale to be projectively larger than the *intersection* scale. It exceeds the *vista* space, thus can be related to the *environmental* space. The related map scale is considered to be relative to the size of the neighborhood.

The *city* scale depicts information about the global context of the city in order to support the understanding of the global city context and the main city structure. It provides an overview of a whole city or, in case of a drive between cities, the area between two cities. Relevant information at this scale are global landmarks, the main street network, and structural regions at a size that does not exceed the size of the particular city. The *city* scale is considered to be projectively larger than the *neighborhood* scale at a map scale that is relative to the size of the city or the area between two cities. Although a city might only

Table 1 Functional Scales in Wayfinding Support.

Functional Scale	Information Content	Function in Wayfinding Support	Related Cartographic Scale	Related Psychological Scale
intersection	– detailed information about DP – building information – local landmarks – full street network	– identification of DP – local orientation – understanding of visual information at DP	fixed large scale *	vista space
neighborhood	– information about local context – local & global landmarks – full street network – structural regions ≤ neighborhood	– understanding of local route context – understanding of surrounding connections	relative to size of neighborhood	environmental space
city	– information about global context of city – global landmarks – main street network – structural regions ≤ city	– understanding of global city context – understanding of city structure and main connections	relative to size of city **	environmental space
region	– information about global context of the region – main street network – structural regions ≥ city	– understanding global region context – understanding of main connections through region	relative to size of cities and regions	geographical space
route overview	– combined information from neighborhood, city and region scale	– understanding of the global route context – getting overview of whole route	relative to length of route	

* e.g., for an average 5 inch smartphone screen this relates to a map scale of 1:1.000 – 1:3000.
** e.g. for the city of Münster, western Germany, this relates to a map scale of 1:100.000 – 1:200.000.

be directly apprehended with a considerable amount of time, it can still be related to the *environmental* space.

The *region* scale depicts information about the global context of the region in order to support the orientation within the region and support the understanding of the overall structure of the region. It only highlights the main street network and structural regions at a size of the cities or larger; more detailed information such as separate instances of landmarks are not considered as relevant for this scale. We consider the *region* scale to be projectively larger than the *city* scale at a map scale that is relative to the size of the particular region. The environmental spaces represented in the *region* scales are too large to be apprehended directly through locomotion, although the related wayfinding scenario involves locomotion through the region; thus the *region* scale is related to the *geographical* space as defined by Montello.

The *route overview* scale depicts information about the whole route in a single map in order to provide overview of the whole route and surrounding environment and to support the understanding of the global route context. While the previous scale categories are considered as not overlapping and ordered from the *intersection* scale to the *region* scale, the *route overview* scale might overlap with the other scale categories. The related map scale of the *route overview* scale is relative to the length of the route such as to contain the whole route in a single map. We consider environmental features relevant for the *route overview* scale to be composed of information from the *neighborhood* scale, the *city* scale, and the *region* scale; this relates to the structure of the particular route. It was shown that routes have a typical structure, which was divided in three parts: a detailed beginning, a coarse middle, and a detailed end [23]. The route structure is considered in the *route overview* scale, e.g., detailed information about the local route context are depicted around the beginning and the end of the route (see *neighborhood* scale); coarse information about the global context of the city (*city* scale) or even the region (*region* scale) are depicted for route parts consisting of higher order streets such as secondary roads, primary roads or highways. Depending on the length of the particular route, only a subset of the functional scale categories might be relevant; e.g.

for a route that lies entirely within a city, the *region* scale is redundant.

Although the functional scales are defined to selectively represent environmental features, this does not solve the problem of small-display cartography to visualize geographic information on small displays with sufficient level of detail. The functional scales are related to map scales, which are relative to the size of the neighborhood, city, or region, or the length of the route. Depending on the actual size of the related features it might not be possible to visualize the defined information content of the functional scales on small displays in a legible way. To cope with this, we refer to ongoing research on the selection of environmental features to support orientation and spatial knowledge acquisition (see [11]).

4 Conclusion

Current navigation systems incorporate different map scales for presenting wayfinding instructions, however, the selection of scale is not supported by psychological findings. We suggest a categorization of *functional* scales of wayfinding maps, which are distinguished by the containment of features relevant for different aspects of navigation. As described above, we suggest that these *functional* scales can have a benefit for supporting wayfinding and orientation if used for providing wayfinding instructions.

In future work, we aim to empirically evaluate the categorization of functional scales in two aspects. On the one hand users' preferences in assisted wayfinding scenarios with respect to the functional scales will be investigated. This aims to get a first insights into and explore the relevance of the functional scales with respect to different route contexts. On the other hand the relevance of environmental features with respect to the functional scales and the effect on spatial knowledge acquisition will be investigated. We thereby target the question what scale is most suited with respect to different functions and contexts in wayfinding and orientation support. Our work contribute to the general understanding of spatial knowledge acquisition in assisted wayfinding scenarios.

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