Enriching Navigation Instructions to Support the Formation of Mental Maps

Monika Sester and Sagi Dalyot

Abstract Navigation systems are widely used today. These systems usually provide turn-by-turn origin-to-destination navigation instructions via visual and audio guidance. Whereas the systems most of the times work successfully, experiments have shown that users have problems in developing survey knowledge of the environment they passed through. This is due to the fact that users simply follow the instructions, without actively mentally mapping their current location in respect to the environment. The research presented in this paper aims at enriching conventional routing instructions with additional information (survey knowledge), which puts the route into the general spatial context and thus facilitates the building up of the users' mental map of the environment. In this paper, first investigations are presented in terms exploring two different data sources for enrichment, namely topographic and VGI data. A taxonomy of relevant features and relations is given, and methods for their automatic extraction and evaluation are described.

Keywords Wayfinding · Mental map · Car navigation · Survey knowledge · Landmarks

1 Introduction and Overview

Navigation devices provide a technical support for efficient wayfinding and navigation, mainly by guiding a user from location *A* to location *B*. This is carried out by turn-by-turn instructions including relative distances and road landmarks, often accompanied by a map overlay, which gives the user an idea about the spatial

M. Sester (✉)
Institute of Cartography and Geoinformatics, Leibniz Universität Hannover, Hannover, Germany
e-mail: monika.sester@ikg.uni-hannover.de

S. Dalyot
Transportation and Geo-Information Engineering, Technion, Haifa, Israel
e-mail: dalyot@tx.technion.ac.il

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context around the route. The users mostly rely on listening and following the instructions. Thus, an explicit acquisition of the spatial knowledge of the area traversed by the route is not needed—and thus usually not done.

Whereas the systems in most of the time successfully solve their main task of guiding users to their destination, experiments have shown that users have problems in developing overview knowledge of the environment they passed through. This is due to the fact that users simply follow the instructions given by the navigation system, without actively mentally mapping their current location in respect to the environment (e.g., acquiring and using spatial survey knowledge). This is different when users analyze a map and structure the route before their trip: they scan the map, identify important locations and landmarks in the surroundings, and more specifically in relation to their planned route, consequently obtaining a general impression of the layout of the environment and the route they have to follow. This leads to the formation of a mental map of the environment. The lack of environmental overview knowledge, as in car navigation, is a deficiency, and as such it may also lead to problems when it comes to react on deviations, e.g. traffic jams or road constructions, and in worst cases it might lead to unsafe driving and accidents.

The research hypothesis described in this paper is that communicating augmented information about objects (and their spatial context) in their environment will help the user to memorize routes better and also explore an unknown area better, thus, aiming to mimic the map study process. This information is in addition to landmarks, which are crucial for wayfinding Fig. 1. schematically visualizes the additional information when going from mere turn-by-turn-instructions, over to a landmark-based description to a description using survey knowledge.

In this way, the navigation process is complemented by an educational experience, which informs users and makes them aware of supplementary spatial information. This process involves the retrieval, extraction and integration of environmental information, and its adequate selection and communication to the user. In this paper, first investigations are presented in terms of spatial data interpretation and retrieval exploring two different data sources for enrichment, namely topographic data and crowdsourced geo-tagged information. Whereas the first provides conventional environmental information, the latter has the potential to

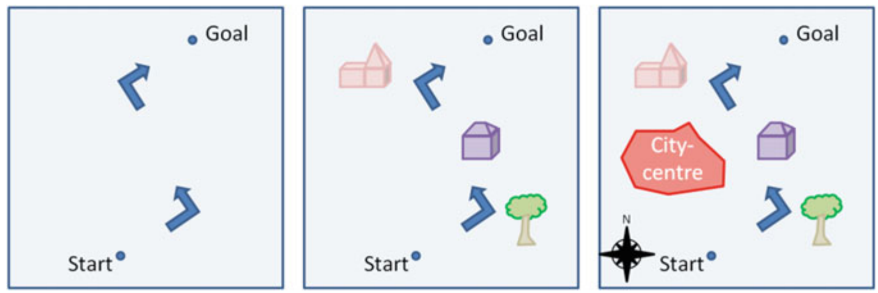

Fig. 1 Turn-by-turn-instructions (*left*); use of landmarks (*middle*); enrichment by survey knowledge (*right*)

supplement with additional environmental information and being better suited to the interests and needs of the users, and thus provides better user adaptability.

The paper is organized as follows: the next section outlines the state of the art relevant for this research, followed by the presentation of a taxonony of important features and relations necessary for conveying survey information. Subsequently, methods for the automatic extraction of these features from geographic databases are sketched and how to link them to a route description via relations. Based on this, examples for route enrichments are shown, which are compared with routes derived from navigation systems. A discussion and an outlook on future work conclude the paper.

2 State of the Art

The research addresses different research fields in the domain of spatial cognition and spatial data processing. The state of the art in these domains will be briefly discussed in the following.

2.1 Conceptualization of Space

The spatial representation of the environment in the human mind is formed from a variety of geographic features. According to Lynch (1960) these can be divided into paths, districts, edges, landmarks and nodes. They include the locations of these features in the environment, the distances among them and the knowledge necessary to orientate oneself in the environment. The primary function of this spatial representation is to facilitate location and movement within the larger physical environment and to prevent oneself from getting lost (Siegel and White 1975). According to Thorndyke (1981) there are three different types of spatial knowledge:

- *Landmark knowledge*: memory of prominent geographic features or objects.
- *Procedural knowledge*: knowledge of route representation, action sequences that connect separate locations, and procedures for navigating between points.
- *Survey knowledge*: knowledge of the configuration of features and the global organisation of those objects and the relationship between different routes.

The author also states that these three types of knowledge are build sequentially; that a person's knowledge typically progresses from landmark to procedural to survey knowledge with increasing familiarity with the environment (Thorndyke and Hayes-Roth 1982). People traditionally acquire environment knowledge through direct exploration of an environment, and/or through indirect methods, such as the study of formal maps, informal sketch maps, verbal instructions, and so on (Burnett and Lee 2005).

2.2 Landmarks and Survey Knowledge—Cognitive Aspects of Wayfinding

The important role of landmarks and survey knowledge for the effectiveness of route directions and descriptions was studied and confirmed by several researchers (Deakin 1996; Denis et al. 1999; Michon and Denis 2001; Tom and Denis 2003). The conclusion made by these researchers showed that survey knowledge having a more absolute reference frame, and not merely in relation and relative to the specified route, produces more broad and comprehensive mental and cognitive understanding of the space and orientation in it. There have been many studies on the role of landmarks on wayfinding, especially on the automation of the process of defining and selecting appropriate landmarks (Raubal and Winter 2002; Elias 2003). Several studies showed that navigation systems contribute much less to the development of cognitive spatial models, as compared to the use of printed maps (Burnett and Lee 2005; Dickmann and Kestermann 2011; Leshed et al. 2008) This has the negative effect that users are lost if they cannot use their navigation systems. Also, it is difficult for them to evaluate alternative routes, e.g. in case of roadblock (Hipp et al. 2010).

Daniel and Denis (1998) analyzed propositions used in route descriptions and came up with 5 classes, two of which only relate to local landmarks in the vicinity (class 3) and their properties (class 4). Schwering et al. (2013) extended this concept by additional classes indicating orientation information, namely orientation using local landmarks, orientation using global landmarks, turning/non-turning movements using local landmarks. In their study with human subjects they revealed that global landmarks were only rarely used in route descriptions. However, they claim that those landmarks would support global orientation.

2.3 VGI—Volunteered Geographic Information

VGI describes a collective and collaborative accumulation of spatial data through a web platform (Goodchild 2007). Although typically VGI data are not as complete in coverage, thematic granularity, homogeneity and quality as authoritative data, they can provide a rich source of complementary information compared to authoritative data (Jackson et al. 2010; Sester et al. 2014). VGI data sources provide large amounts of personal knowledge, and thus hold a great potential for improving the quality of existing spatial databases used for navigation and Location Based Services (LBS). The exploitation of VGI for different purposes is currently actively researched, e.g. in the context of catastrophe management (Dittrich and Lucas 2014; Fuchs et al. 2013). Furthermore, VGI can be used as data source for the retrieval of more informal information, such as vernacular places or local knowledge, which often is not represented in maps, although heavily used by people in their daily lives. The automatic extraction of such information has been investigated by several researchers (e.g. Jones et al. 2008; Paelke et al. 2012). VGI have the potential to provide timely and immediate information, because the update process of such data is usually event based (and not time based as in authoritative data).

3 Taxonomy of Survey Information for Formation of a Mental Map

The type of information required for enriching conventional routing has two components: one that relates to general environmental information; the other that refers to individual information, and thus takes individual preferences into account. The assumption is that the former information gives orientation concerning visible topographic objects ("crossing the railway line"), while the latter supports memorizing, as it includes emotions and thus is of relevance for the individual ("the junction where the famous/your favorite restaurant is").

Besides conveying specific objects in the local environment of users on their routes, also basic fundamental concepts should be provided, which embed these features in a broader spatial context, such as cardinal directions, relations to other (known) objects. The abstraction and integration of both delivers with survey knowledge, such that the mental representation of this knowledge can be considered as "cognitive map" (Sholl 1987).

When selecting features, saliency plays a crucial role: this has been investigated for landmarks e.g. by Raubal and Winter (2002). In this way, characteristics of landmarks were identified, which support the immediate perception but also visual distinction of different objects. In the following, the investigation of Elias (2002) is used as a basis for defining relevant survey information, which is extended by additional relational features.

3.1 Information from Topographic Maps

The following list of objects from a digital topographic map is examined for features and attributes, which can enhance a route description by providing orientation information. These are objects directly crossing or bordering the route, objects in the vicinity, or objects which are important due to their size, their regional or global relevance and also visibility. Importance can be measured by a certain attribute (size, form) or derived from the proper name (e.g. church).

In the topographic data set of Germany (ATKIS), the following object classes have been identified:

- Transportation:
  - road traffic (e.g. roads)
  - rail traffic (e.g. tram rails, railroads)
  - traffic infrastructure (e.g. tunnels, bridges)
- Water:
  - sea, lakes, ponds
  - streams, rivers, creeks
- Settlement:
  - built-up areas
  - industrial areas
  - open areas with specific function (sports facilities, zoos, ..)
  - special buildings and facilities (towers, monuments, ..)
- Vegetation:
  - forests
  - gardens, parks

From cadastre, in particular the following information is relevant:

- Buildings:
  - Large buildings
  - buildings with special, extraordinary, remarkable shape
  - buildings with specific use (name)
- Important infrastructures:
  - railway stations
  - airports.

3.2 Information from VGI

Since VGI data is maintained by the public and various sources exist, no single and consistent catalog is maintained, as in ATKIS data. VGI platforms considered here are not characterized as GIS ones (such as OSM), such that they are not geographic platforms in nature. Therefore, VGI datasets considered at this stage are the ones explicitly storing position tags (geo-tagged); these are later geo-registered to the extent of the topographic maps, emphasizing on the retrieval of complementary semantic attractions that might not exist in authoritative datasets.

Two volunteered data sources are considered and analyzed here: *Wikipedia* (wikipedia.org) and *foursquare* (foursquare.com). Wikipedia is used here for the retrieval of cultural, architectural and historical objects, as well as other geographic features (such as water bodies). Foursquare, maintained and ranked by the public, delivers a list of attractions that are less touristic-oriented and more recreational; e.g., coffee houses, art galleries, restaurants. The update-rate of foursquare is very frequent (updates are aggregated as '*check-ins*'), offering the possibility of turning all features existing in the spatial extent into a 'venue' (feature), thus the density of spatial features is very high.

3.3 Overall Basic Concepts in Cities

In the conceptualization of the environment, people are using also overall concepts and vernacular descriptions, e.g.:

- city center
- old town, historical center
- urban districts
- ring roads

Such implicit information can be extracted from VGI data (e.g. Jones et al. 2008; Lüscher and Weibel 2013) or from topographic data based on spatial data interpretation (Heinzle and Anders 2007).

3.4 Spatial Relations

It is very important to link the different concepts with each other, with the route, and the current position of the user. In the following, some important relation concepts are listed:

- directions and cardinal directions (e.g. North, South, Northwest)
- in front of
- right of, left of
- towards (north, south, …, object)
- close to/near/next to
- passing through (e.g. city center, harbor area, …)
- passing at the border of
- passing at the northern border of
- between x and y (e.g., between river and city center)
- crossing (e.g. route crosses railway line).

4 Extraction of Survey Information from Spatial Data

The information defined in Sect. 3 can be retrieved from existing spatial information in different ways. On the one hand, some of the information is explicitly modeled in the spatial data sets and thus it can directly be selected and used. In our case, the topographic data is retrieved based on this approach. On the other hand, some information has to be aggregated and/or interpreted from the given information, e.g. the size of an industrial area has to be computed after all the individual industry objects have been merged. Also, additional attributes can be calculated or determined, which allow attaching a measure of salience or relevance to the objects.

In the following, it is assumed that topographic data can be selected according to given criteria, whereas the selection of relevant information from large collections of VGI data is a challenge.

4.1 Extraction of Survey Information from VGI

For the retrieval of Wikipedia features (entries), the Wikipedia API[1] is used based on SQL format. Two options are available for the retrieval of geographic entries: either by a bounding box or by a radius search. The use of *Location*, *Geographic coordinates*, and *Category* tags of the Wikipedia entry are used to retrieve the semantic attractions desired. In order to be able to assign a ranking weight (significance measure), i.e., the potential a feature has in contributing to a better cognitive appreciation and understanding of the space the user is in, the following entry attributes (tags) are considered:

- *Date of page creation*—the "older" the entry is, the more significant and important it might be
- *Total number of edits* and *Date of latest edit*—more edits exist meaning that the entry is more significant and being updated
- *Total number of distinct authors*—more distinct editors exist meaning that the entry is more significant, important, and reliable
- *What links here*—more links exist mean that the entry is relevant to various categories and other entries, i.e., its hierarchy might be high
- *Page view statistics*—high entry views implies that an entry is of interest

All attractions existing in foursquare have a *rating* (on a scale of 0–10). Foursquare entries are retrieved with the help of the foursquare API,[2] according to the entry position (coordinates). Additional parameters can be used to tune the query, whereas here the use of *section* was implemented, retrieving features categorized as *outdoors* and *sights*. Other attributes used for significance measure are:

[1] https://www.mediawiki.org/wiki/Extension:GeoData.

[2] https://developer.foursquare.com/docs/venues/explore.

- *checkinsCount*—total number of users "visits", i.e., check-in, to the feature; the higher the value implies the features is of an importance
- *usersCount*—total number of unique users "visited" (checked-in) the feature; the higher the value implies the feature is of an importance
- *tipCount*—total number of tips given to the feature
- *numPhotos*—total number of photos uploaded by users to the entry page.

4.2 Determination of Spatial Relations Between Features

The relevant features are not merely listed, but they have to be linked to the route, which the user is taking. This is achieved using spatial relations. They have to be extracted using spatial operations in a GIS or in a spatial database. Some of them are directly available as implementations (e.g. topological relations using 9I-model); some have to be developed and implemented. In the following, a preliminary list of operations is given for the realization of the above mentioned relations.

Directions can be determined as heading angle towards an object with respect to the north direction; thus the operator takes two points as input, as well as a direction angle and a tolerance angle (depicted in Fig. 2).

Cardinal directions can be determined by a variant of the direction operator using appropriate values for the angles (e.g., direction north: $\boldsymbol{\beta} = 0\,^{\circ}$, $\boldsymbol{\alpha} = 45\,^{\circ}$).

Van Kreveld and Reinbacher (Van Kreveld and Reinbacher 2004) describe an algorithm for partitioning a polygon into compass directions, to determine the cardinal directions within a polygon object. In this way, information such as "in western part of the city" can be created.

Towards < cardinal direction or object > can be calculated using the current heading intersected with a target object or target direction. It can be realized with the direction operator.

In front of can also be realized with a variant of the direction operator (depicted in Fig. 3):

Right of, left of can be determined based on a given orientation of an object and an analysis of direction angles.

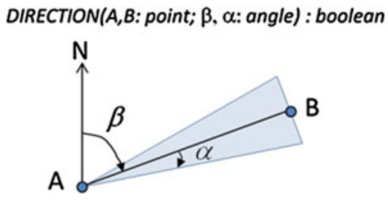

Fig. 2 Direction operator: input two points (A, B), direction angle β and tolerance angle α

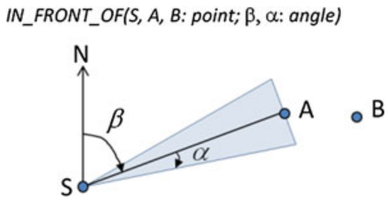

Fig. 3 In front of operator: related to start point S and destination point A that lies in front of point B

Near, close to, next to is an operation that has to take the distance of two objects as well as their importance into account, e.g. for an airport, a larger distance can be used to be considered as near as opposed to a small coffee-shop. This can be formalized using an exponential function of the distance (Arampatzis et al. 2006), depicted in Eq. 1 and Fig. 4.

$$near(A, B) = \exp(-L * D(A, B)) \tag{1}$$

where A and B are the centroids of the two (point) objects, D(A,B) is their Euclidian distance. Thus, proximity scores decay exponentially from 1 to 0 with increasing distance. L controls the rate of decay and has to be set according to the importance of the object: a large object like an airport has a small L-value, leading to a slow decay.

Passing through is an operation on a line and a polygon feature and can be realized using the overlay or intersection function from the 9I-model. It can be refined by comparing the relative sizes of the areas that are partitioned by the linear object into "passing through the middle", or "passing in the northern part of". The relation "passing at the border of" can be realized using the touch relation.

Crossing is an operation which relates to two linear features and is realized with an intersection operation (e.g. crossing the railway line).

Between: x and y (e.g. a road between river and city center) can be determined by analyzing the relative ordering in the neighborhood of three objects.

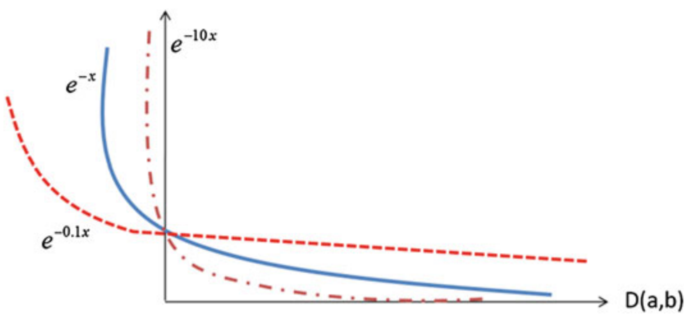

Fig. 4 Near-Operation: function of distance and decay factor; low value (e.g. 0.1) leads to slow decay, corresponding to a large neighborhood

5 Combination of Routes and Survey Information

In order to enrich a given route with survey information, an appropriate selection of relevant objects has to be made; relevant objects do have a relation with the route, namely:

1. they are adjacent to or cross the route (e.g. railroad)
2. they have a certain importance
3. they are of local perceptual significance, as they are directly visible from the route (e.g. city hall on right hand side of the route)
4. they have regional or global relevance and thus are put into a spatial context with the current location (position and heading) on the route

The regional or global importance of an object can be determined from the function or name of the object (e.g. Opera house, TV tower). Winter et al. (2008) propose an alternative by creating a hierarchical ordering of (landmark) objects based on a saliency criterion (Elias 2003). In VGI data, as explained above, the notion of relevance can be determined using the ranking or rating measures.

The concept for combining the survey information with a given route is as follows:

1. Identification of survey knowledge elements in the local environment around the route (buffer).
2. Determination of spatial relations between the route and the extracted elements.
3. Identification of global features in a larger environment of the route.
4. Determination of spatial relations between those features and the route.

As a result, the route is enriched with additional survey information. Besides only naming or mentioning the objects, also further information about the objects can be communicated, e.g. when the historical church was built and by whom.

6 Examples

6.1 Data Retrieval from VGI

Entries and places from in the area of Hannover city, Germany, were retrieved based on the concepts detailed in Sect. 4.1. In Wikipedia, two main data sources were considered: the German Wikipedia-DE, and the English one-EN. Since route examples analyzed are in Hannover, more DE entries were retrieved than EN ones: 721 and 124, respectively, detailed in Table 1. Though the DE data is much more complete and has much more details, it was found that all EN entries retrieved had DE ones as well, and perhaps more important—the majority of significant features (i.e., high count of entry parameters used for ranking) existed in the retrieved data. Such as historic, transportation (main train stations and airport), cultural and architectural objects, university. It was hard to use the DE *category* tag, since no consistent classes

Table 1 Number of entries retrieved for DE and EN Wikipedia

Feature type	EN (total = 124)	DE (total = 721)	Description
City	26	21	Different districts existing in the area
EDU	2	–	Universities
Landmarks	64	596	All types (churches, museums, statues, …)
Mountain	4	2	–
Railway station	12	12	Mainly high speed train stations (not trams)
River	3	1	–
Water bodies	4	4	lakes
Null	9	94	–

were used (for example: Marktkirche in the city center is categorized under "church" in the EN entry, whereas in the DE entry it is categorized under 10(!) different sub-categories). Also, the use of native-language ("local") Wikipedia holds a great challenge, since additional language barrier exists in building the required taxonomies. Moreover, the DE data consisted of many entries that could be considered as irrelevant, for example: local shops and entries having a geo-tag but present only general knowledge (football games took place in Hannover in 2003). Consequently, only the EN entries were considered at this stage.

In the analysis of foursquare data, the focus here was given to two main categories considered of having more relevance to wayfinding: *outdoors* and *sights*. In contrast to Wikipedia, the type of venues (named categoryName), was fairly easy to retrieve, and was clear and easy to identify into taxonomies (for example: Plaza, City Hall, Monument/Landmark, Garden, Church). A first impression on the retrieved places seemed very promising, since it was found that many geographic features, which we did not expect to find, did exist in foursquare, namely city districts (*Neighborhood*), together with other features that did not exist in the EN Wikipedia. However, *rating* parameter was found unusable since it did not exist in most entries. Alternatively, the other parameters suggested in Sect. 4.1 were used, which had a very high correlation, depicted in Table 2 (*summary* in Table 2 represents the number of "likes" users-comments for a venue).

Table 2 Feature statistics of different relevance parameters in foursquare

Name	Category name	Checkin count	Users count	Num photos	Summary
HDI Arena	Soccer Stadium	3899	1435	254	109
Kröpcke	Plaza	3517	1199	113	16
Maschsee	Lake	3208	1265	254	48
Leibniz Universität Hannover	University	2652	503	58	11
Zoo Hannover	Zoo	2340	1186	175	115
Ernst-August-Platz	Plaza	2058	676	25	9
Neues Rathaus	City Hall	1843	934	265	18

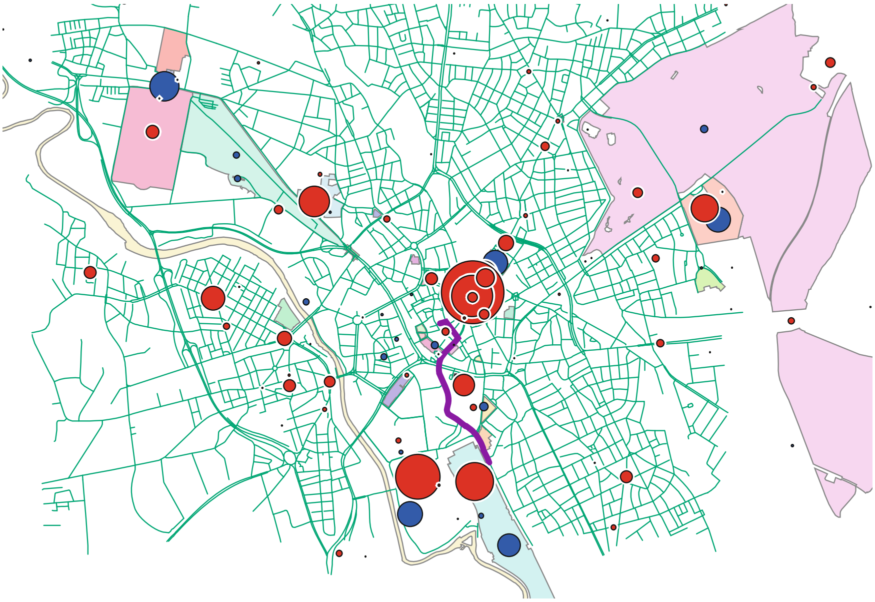

Fig. 5 VGI features retrieved for the centre of Hannover superimposed on the road network and topographic features (*polygons*). *Circle* depicts the features' ranking (some features are not visible having low ranking), *blue* Wikipedia, *red* foursquare

Figure 5 gives a general impression of all features extracted by all available sources. It is interesting to observe that, while there is an overlap of features in the data sets, as expected VGI data contributes with local information specifically about places, and—in principle, but not analyzed here—with additional information such as shopping centers, restaurants, leisure places. The large pink area in the East symbolizes a large forest (Eilenriede), whereas the rectangular polygon in the West is the famous Baroque Garden; next to it, in green, is the George's Garden.

6.2 Route Examples

In the following, example routes have been selected and enriched with the survey information (Fig. 6 and Fig. 8). The descriptions are compared with a conventional routing instruction from Google (Fig. 7 and Fig. 9). It has to be noted, that conventional routing instructions do serve another purpose (only wayfinding and guiding), and thus are mainly based on directions and street names. Still, the comparison with the survey information shows the richness of the information conveyed.

6.2.1 Example 1

In Google Maps, Route 1 is described in Figs. 7:

Using the proposed concept, the following information will be conveyed along with the routing instructions:

1. your start is in the district Herrenhausen, which lies in the north west of the city; on your right you should see the new Herrenhausen castle; drive along Herrnhäuser Straße in eastward direction; you enter the district Nordstadt
2. continue on Nienburger Straße in direction south-east, the route heads all the way towards the Neues Rathaus (city hall)
3. you will drive along the north-eastern border of the Georgengarten with the Wilhelm-Busch Museum on your right
4. To your left, you see the Welfenschloss, the main building of Leibniz Universität Hannover
5. continue on Königsworther Platz and then turn right onto Königsworther Straße and drive southwards

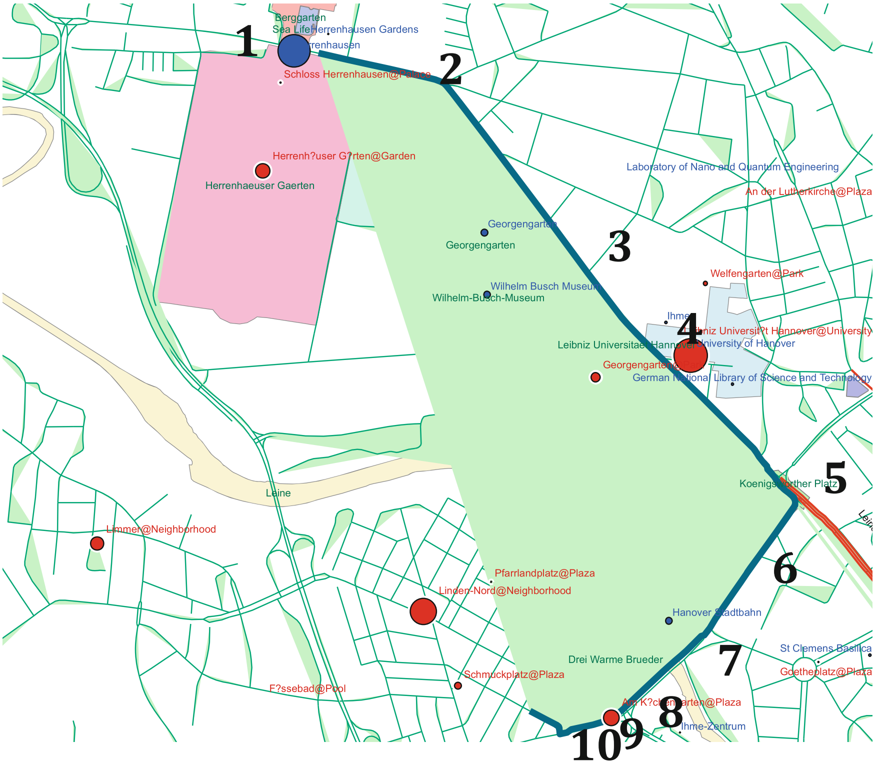

Fig. 6 Route 1: origin (*top-left*) to destination (*middle-bottom*) with route labels of enriched routing instructions

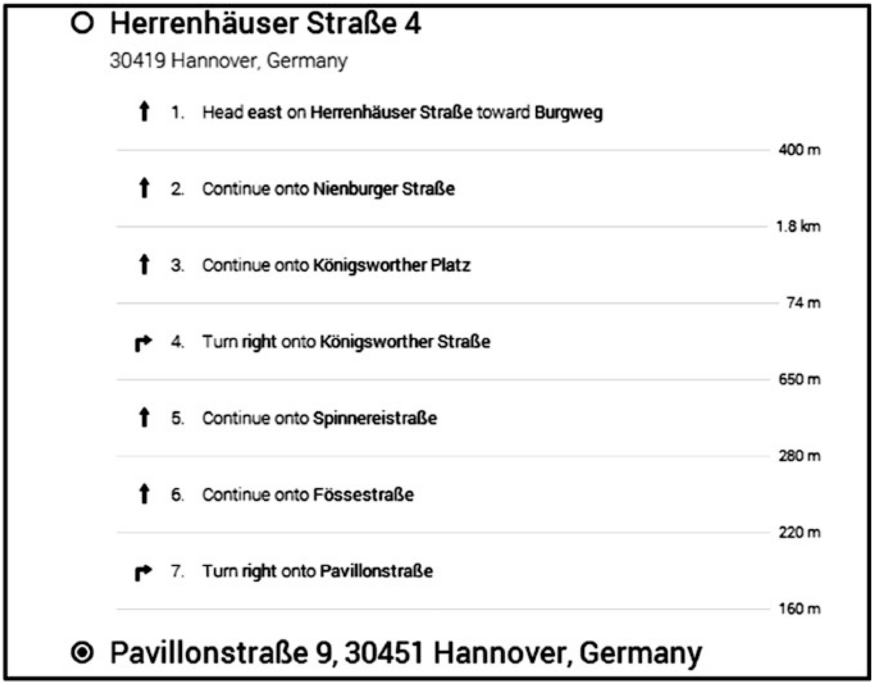

Fig. 7 Instructions for route 1 given in google maps (*source* google maps)

6. you are now in the district Calenberger Neustadt, which is located west of the city center
7. you will now cross the river Leine and reach the city district Linden-Nord; continue straight on Spinnereistraße
8. On your right hand side you pass the huge heating plant with its three towers; it is colloquially called “drei warme Brüder”—the three hot brothers
9. You now access Am Küchengarten plaza
10. turn right into the Pavillionstraße towards Linden-Nord centre.

In this way, both information about local points of interest is given, but more importantly, general survey information is conveyed, which locates the objects into a reference frame, e.g. with compass bearings, and with reference to other objects. According to Thorndyke and Hayes-Roth (1982), survey knowledge includes in addition also distances between the objects. This is not yet included in the proposed concept, and is subject to future work.

6.2.2 Example 2

In Google Maps, Route 1 is described in Figs. 9:

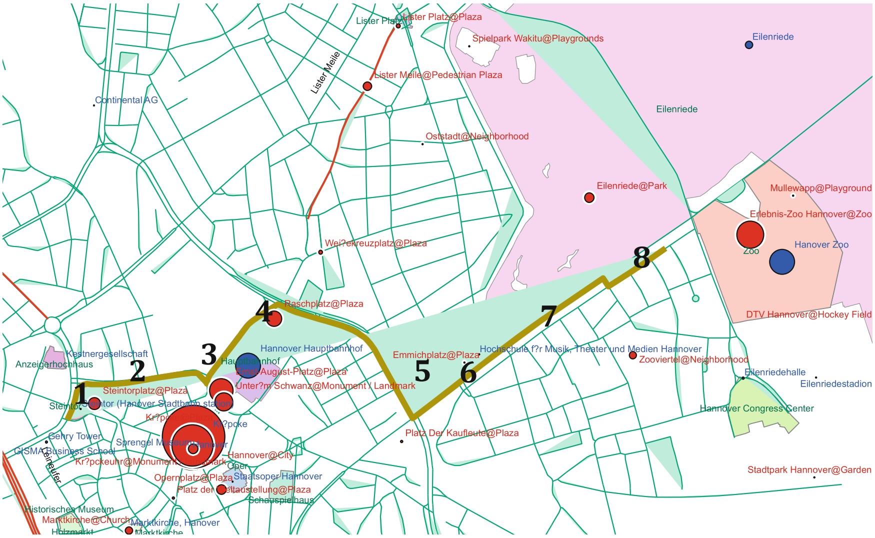

Fig. 8 Route 2: origin (*middle-left*) to destination (*top-right*) with route labels of the enriched routing instructions

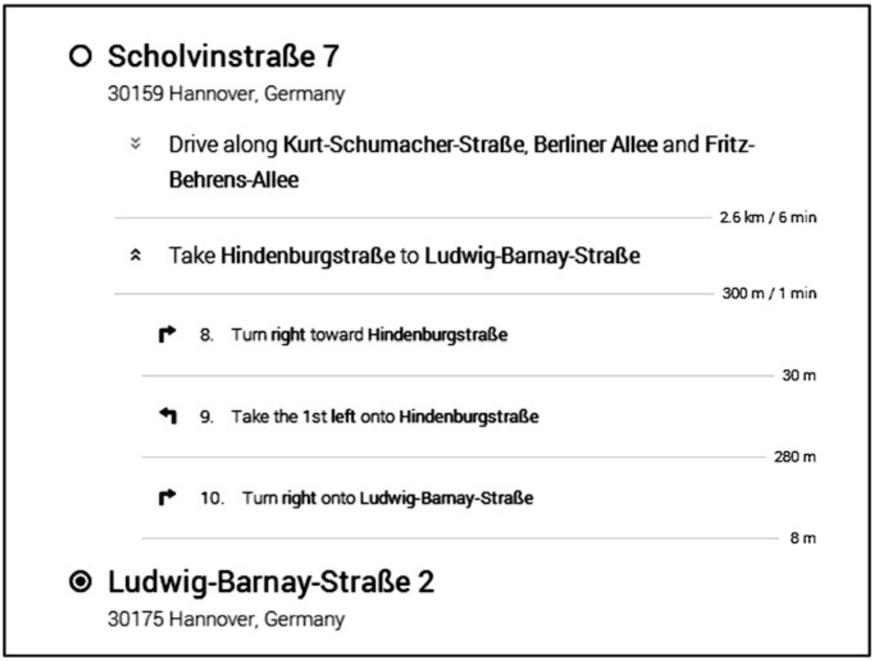

Fig. 9 Instructions for Route 2 given in Google Maps (*source* Google Maps)

Using the proposed concept, the following information will be conveyed along with the routing instructions:

1. Your start is in the quarter Steintor, which lies in the west of the city centre; on your right you should see the Steintor subway station and Georgstrasse which leads to Kroepke Plaza—the city centre; drive north along Am Steintor
2. continue right on Kurt-Schumacher in direction north-east, the route heads all the way towards the central train station (Hauptbahnhof)
3. Approaching central train station, before head left, you should see ahead of the Ernst-August-Plaza with the "Unterm Schwanz" monument—a statue of King Ernst-August I on horseback.
4. Drive north while the central-train-station is on you right on Raschplaz, and turn right when approaching on Raschplatz plaza; this is one of Hannover's main entertainment centres with a large cinema complex.
5. Drive eastwards along Berliner Allee until the next main intersection
6. Head left northwards towards Zooviertel neighborhood, which holds the Hannover Congress Center
7. Continue straight while you pass on your left the Eilenriede park—one of Germany's largest urban parks
8. While approaching your destination you will see the Hannover Zoo with its attractions.

7 Conclusion and Outlook

In the paper, a concept for the enrichment of routing directions with additional survey information is proposed. The features have been selected based on a literature survey. A selection of features is presented, which can be found either in digital topographic maps or in VGI data, and methods for their automatic selection are described. Exemplary route descriptions have been manually created using those features and linking them to the route with spatial relation expressions.

There are several issues that will be investigated in the future. An important topic is the conducting user experiments in order to verify the hypotheses set up in this paper concerning their influence on the human cognition. To this end, tests will have to be conducted, where a group of test people who used enriched route descriptions have to solve some tasks, as opposed to ones, who used conventional navigation instructions: e.g., draw a sketch map of the environment, describe the route in the reverse order, or answer questions concerning the overall structure of the environment. Based on these investigations, further refinements on the features and relations involved will be conducted. It is also expected that the type of features used will differ with increased familiarity of the users with the environment. An interesting topic will be to identify which type of feature is useful for which degree of familiarity.

Concerning VGI additional investigation is required into the retrieval of the most significant information, in terms of the feature itself, but also in terms of user-specifications (e.g., preferences or wayfinding purpose), and perhaps in terms of LBSN and recommendations from other users. Another aspect is the filtering-out of duplicated features retrieved both from the VGI and topographic datasets. Still, the use of VGI has important benefits, in that firstly it allows to present supplementary as well as user-adapted information. Secondly, from social media data, the notion of relevance can be directly extracted, e.g. the popularity of a place and its purpose.

All in all this process has great potential in addressing cognitive problems associated with the building up of a mental map, but also in terms of user-defined requirements and the exploration of new places.

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