



Spatial Distribution of Local Landmarks in Route-Based Sketch Maps

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Abstract. Landmarks are important elements in route instructions communicated for wayfinding in unfamiliar environments. This paper aims to investigate the distribution of local landmarks in human sketch maps provided for wayfinding purpose. We investigated sets of route instructions given by student participants who were asked to give directions in environments that they are very familiar with to someone unfamiliar. These environments differ in size as well as their relation to city centers. In particular, one route goes into the city, one route goes through the city center, and the third route ranges between two cities. The results show that local landmarks are distributed differently in each route and showing high density of landmarks at some portions of the route. The study further clarifies the distribution of landmarks along routes with relation to the length of the route. It also contributes to the work concerning the cognitive aspects of wayfinding with a specific focus on the distribution of landmarks in route instructions.

Keywords: Local landmarks · Route instructions · Sketch maps
Wayfinding

1 Introduction

Assume that someone asks you for directions at the train station or in a supermarket for going to a place that you are familiar with. Which types of information would you provide to help the person reach his/her destination and at the same time learn about this area? Allen [1] emphasizes that there are principles behind how people provide wayfinding instructions. People's knowledge corresponds to the physical environment such that they are capable of producing 'cognitive spatial descriptions' [2]. Differences in route descriptions depend on several factors such as the mode of used transportation, the distance, and the time it takes to arrive at the destination. It is important that a 'common ground' is established [1] for the direction provider and the recipient. This common knowledge serves as a basis for effective understanding of the instructions for the wayfinder. In this paper, we investigate local landmarks oftentimes mentioned in three routes using different mode of transportation regardless of the route choices of participants and where the landmarks are concentrated in the entire route.

1.1 Importance and Characteristics of Landmarks

Landmarks are important elements for acquiring spatial knowledge in an unfamiliar environment. Most people rely on landmark information when asking for giving route directions as this makes it easier for them to remember. In wayfinding-related studies, many researchers from the fields of cognitive science, geography, computer science, psychology, and linguistics have developed systematic methods for analyzing verbal descriptions. For example, these methods include analyzing landmark characteristics [3], propositions of spatial descriptions [4] to understanding ontologies [5] and building up a taxonomy of a wayfinding task [6].

Studies on analyzing landmark characteristics range from different types of spaces. This includes investigating saliency of landmarks in indoor space such as airports [7] and outdoor space analyzing buildings in a city [8]. A formal model of salience was developed focusing on visual, semantic and structural properties of landmarks [9]. This framework then further investigates structural salience of landmarks regarding where they are located along the route [10]. For instance, it was suggested that the saliency of landmarks at decision points [11] depends on the direction of travel. Sorrows and Hirtle [3] identified certain characteristics that make landmarks stand out in the environment for real and virtual space. These are cognitive, structural, and visual elements. The authors emphasized that when navigating in a familiar environment, there are more visual and cognitive types of landmarks used. But in unfamiliar environment, it calls for more visual and structural forms to help maintain orientation and form a cognitive map. Cognitive landmarks are suggested to play an essential role in orientation for a familiar environment. We aim to evaluate this aspect in this paper in order to specify where specific landmarks are mostly mentioned in the instruction of someone familiar with the environment to a complete stranger. Schroder et al. [11] emphasized that visibility of features should be taken into consideration in route instructions. Since Dale et al. [12] pointed out that people tend to use visible features for turning action, we will further evaluate this aspect in the route instructions provided in this study.

1.2 Location of Landmarks

Human-generated route instructions consist of mostly local landmarks [13]. They are suggested to be included in route guidance as it is a natural way of how people provide instructions [12, 14, 15]. In addition to the importance of landmarks in route instructions, location of landmarks has been extensively studied in order to know which landmark should be included in the route instructions. Should it be located along the route, at decision points, or distant from the route? The role of landmarks at decision points has been addressed specifically regarding where turning action is needed [16, 17]. The combination of having action with a landmark, as suggested in the skeletal description developed by Denis [4], has been extensively used and tested successfully in experiments regarding its efficiency was in wayfinding tasks [18, 19]. While many studies have considered landmarks at decision points essential in wayfinding studies [14, 20, 21], landmarks along the route are also mentioned when giving verbal instructions [22]. Its importance and usefulness in wayfinding, however, are not extensively investigated.

Sadalla [23] investigated the importance of reference points in establishing spatial relationship within the environment. Reference points refer to places whose locations are well known which are referred to other adjacent places. These can be used in organizing spatial features in space as it is said to be easier to orient a specific place to a reference point than to a non-reference point. These reference points are already stored in a person's mind and usually retrieved when relating to a non-reference point.

Regarding concentration of landmarks, more landmarks are mentioned at the end of a route [24]. That is to say, there is an increase of landmarks when going towards the end such that the person is able to fix his location during wayfinding. Brosset et al. [25] investigated wayfinding in a natural environment and showed that there were more landmarks mentioned at the end of the route. However, Lovelace et al. [22] showed a different result stating that there is no evidence that more landmarks should be mentioned at the end of the route. It showed in the experiment that no landmark was mentioned at the end of the route in their cases. Consequently, this claim relies on the availability of landmarks or the type of environment. With these factors in mind, we further investigate in this study if the use of landmarks at the end of the route is based on factors such as the type of environment and the mode of transportation. It is important to point out that the previous studies on the use of landmark are based on collected verbal descriptions. Although we consider using the similar method to collect wayfinding directions in an earlier study [26], the authors suggested that in general sketched maps consist of more landmarks than verbal descriptions. Therefore we aim to use the method of using sketch maps as the way of collecting wayfinding instructions to collect as many landmarks as possible for our investigation. The extracted landmarks from sketch maps will become the main database in this study.

1.3 Landmarks in Sketch Maps

There are many ways for communicating route instructions. Human generated instructions are qualitative. It involves extensive use of landmarks to enable one to put oneself of the receiver's perspective [27] and select a route with fewer number of turns [28]. But, it is difficult to teach the computer how to communicate space like humans do [27]. There have been several attempts to computationally extract landmarks from spatial databases [29] or web harvested data [30, 31]. All approaches rely on the salience categories by Sorrows and Hirtle [3]. They first extract potential landmark candidates before refining the selection to the most salient landmarks in terms of visual, structural and semantic salience. Furthermore, there are approaches to automatically include landmarks in wayfinding instructions [13, 30–32]. For this study, we focus on the use and distribution of local landmarks in sketch maps for routing irrespective of the route choice.

The goal of this paper is to determine where local landmarks are situated in the entire route in human sketch maps. We hypothesize that the composition of landmarks varies with the type of route and a certain portion of the route shows higher density of landmarks. The paper is structured as follows: Sect. 2 explains the experiment design. Section 3 discusses the results. Section 4 provides the discussion and Sect. 5 gives the conclusion and outlook.

2 Methods

2.1 Participants

There were a total of 20 university students (10 M, 10 F) with a mean age of 22.9 years ($SD = 2.93$) who participated in the experiment. They were all German native speakers who have been residing in the student dormitory for at least six months and claimed to be familiar with the study area. The participants were from various disciplines. They were paid 10€ per hour for their participation.

2.2 Materials and Methods

Each route was drawn on an A4 paper. We collected a total of 60 sketch maps. Each participant had to describe three routes in the experiment. The study area was in the city of Muenster, Germany. The first route, about 1.2 km (going to city center), was from a train station (Hbf) to the cathedral (Dom). The second route (passing the city center) was a longer route approximately 5.2 km, which was from a supermarket (Lidl) in Gievenbeck neighborhood to the train station (Hbf). The third route (intercity route) was from the dormitory to their hometown in Germany; hence, different routes were taken among participants. In particular, we asked participants who are familiar with the environment to give route descriptions to someone new in the area using bike for the Route 1 and 2 because this is the frequent mode of transportation in Muenster and using car for Route 3 as this is a longer route connecting different cities. All participants drew the routes in similar order.

German students living in a dormitory were invited to participate in this experiment. A questionnaire was given to evaluate their familiarity. They were asked to draw a sketch map of three different routes. They were given a paper and a pen to draw each map. No additional information was given to them on how to draw a sketch map, for as long as they describe a comprehensible route to someone who is new in the area.

Regardless of the route described, we went through sets of sketch maps and analyzed all the local landmarks that people include in the instructions. The analysis was focused on *local landmarks*, meaning those landmarks situated along the route both at decision points and non-decision points.

In the analysis, we divided the route into segments. For the purpose of this study, route segmentation refers to (a) nodes where a decision is made and (b) route segments between two decision points. The road network is represented as a graph $G = (V, E)$ consisting of a set of nodes (V) and edges (E), and a route as a directed graph $G'(V', E') \subseteq G$ from origin $o \in V$ to destination $d \in V$. Each route consists of a set of decision points $D \subseteq V'$. Decision points are defined by a set C of decision point classes, represented by a function $class : D \rightarrow C$, such that for every $d \in D$, $class(d) = c, c \in C$ (see Table 1). The “straight on” decision point determines to only add a decision point of this type when there is an intersection with a street of the same or higher class. The “exit” decision point specifically refers to highways, as there are no junctions on highways, but highways are only connected via exits. The location of a $d \in D$ is represented by the distance from the origin: $dist(d) = d(o, d)$.

We normalize the distribution of $d \in D$ along the route by a normalization function:

$$\text{normdist} : D \rightarrow [0, 1000]$$

such that

$$\text{normdist}(d) = \frac{\text{dist}(d) * 1000}{\max(\{\text{dist}(d') | d' \in D\})}$$

3 Results

It showed that participants provided different route choices from the origin to the destination. Although participants included global landmarks (off-route) in their sketch maps, only local landmarks are considered as points were analyzed in this study (see Figs. 2, 4 and 6). Global landmarks are included only for visualization purpose. The total number of local landmarks provided for each route are 64 (Route 1), 105 (Route 2) and 63 (Route 3).

Among all participants, more than half of them described the same route for sketch maps for Routes 1 and 2. Figures 1 and 3 show the different routes participants described and highlights the frequently taken route in Route 1 and Route 2.

Figure 2 shows the distribution of landmarks on Route 1 at a normalized distance scale from 1 to 1000. For the largest part of the route, there is a low frequency of local landmarks of maximum five landmarks per range. However, the histogram clearly shows that there are a lot more local landmarks towards the end of the route. With regard to the decision point distribution, there are more landmarks drawn when the type is 'straight on' and when turning action is required. The colors relate to the classification of decision points, as presented in Table 1.

Table 1. Classification of decision points along a route.

Decision point (DP) class	Type of decision point
0	Start/destination
1	Straight on (same class or higher)
2	Turn not at a junction
3	Turn at T-junction
4	Turn at junction
5	Turn at roundabout
6	Exit (only for motorways and trunks)

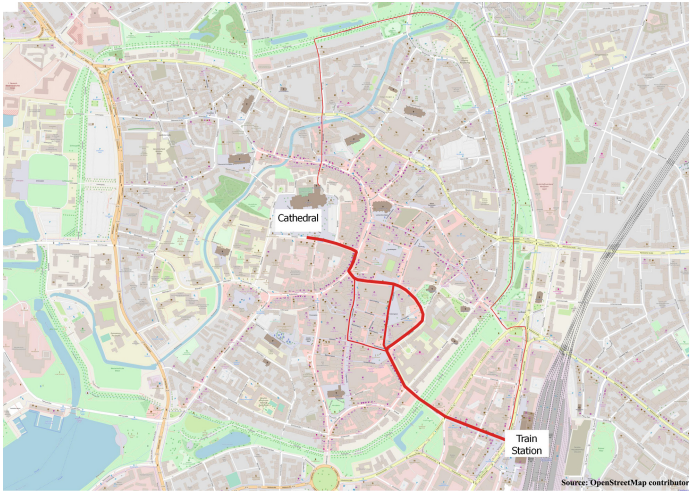


Fig. 1. Route choices for Route 1 (Hbf-Dom). The thick line represents the most frequently referred route. Source: OpenStreetMap contributors

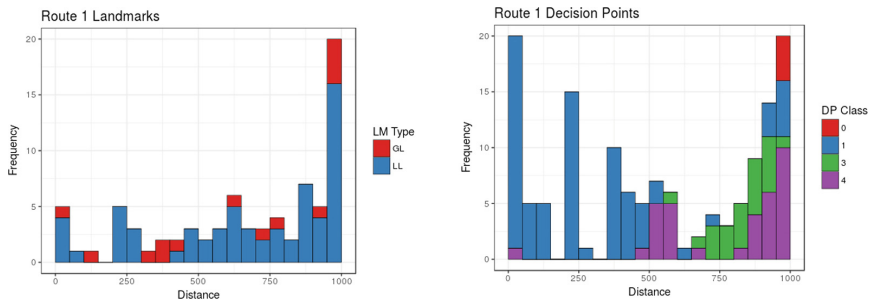


Fig. 2. Histogram of distribution of landmark and decision points (Route 1).

In the case of Route 2, Fig. 3 shows the most preferred route by the participants from a supermarket (Point A) to the central train station (Point B). The thick line shows the most frequent route used by participants.

Figure 4 shows the distribution of landmarks on Route 2 considering the different routes taken. It is again plotted onto a normalized distance scale from 1 to 1000. The peak of more local landmarks mentioned was in both start and end part of the route. But, there are also many landmarks drawn in between the whole route. Participants drew landmarks at almost all decision point classes with more landmarks were drawn in class 'straight on'. When there is a presence of roundabout, participants oftentimes include this in their sketch map.

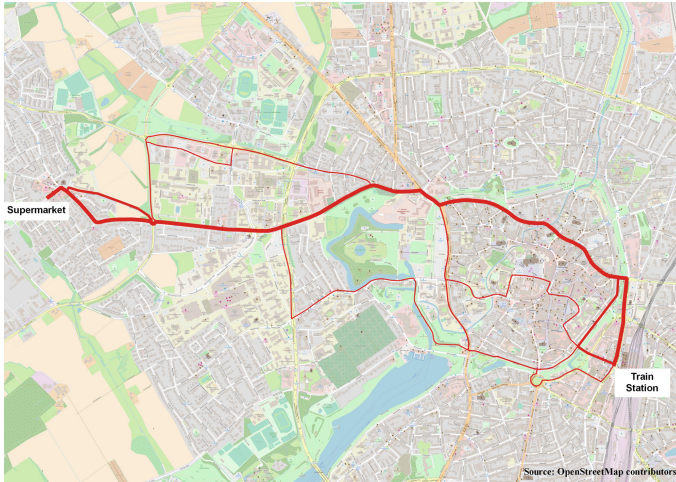


Fig. 3. Route choices Route 2 (Supermarket-Hbf) and the most frequent route is in thick line.

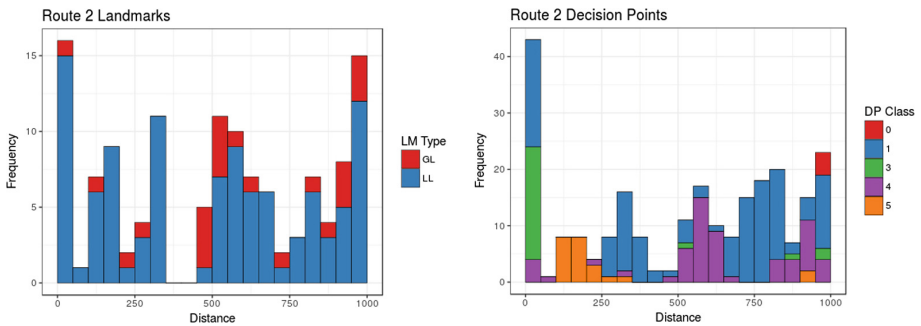


Fig. 4. Histogram of distribution of landmarks and decision points (Route 2).

Figure 5 shows the different routes of participants from the dormitory to their hometown in Germany. The route length ranges from approximately 45 km to 550 km. The longest route was a route from the dormitory in Muenster to the participant’s home in Dresden.

Figure 6 shows the distribution of landmarks on Route 3 on a normalized scale considering the different routes taken. We can again see peaks of more landmarks at the start and at the end of the route. The histogram also shows the distribution of decision points, normalized to a distance scale from 1 to 1000 m. This reveals that landmarks are found in all types of decision point classes with more on ‘straight on’ class.

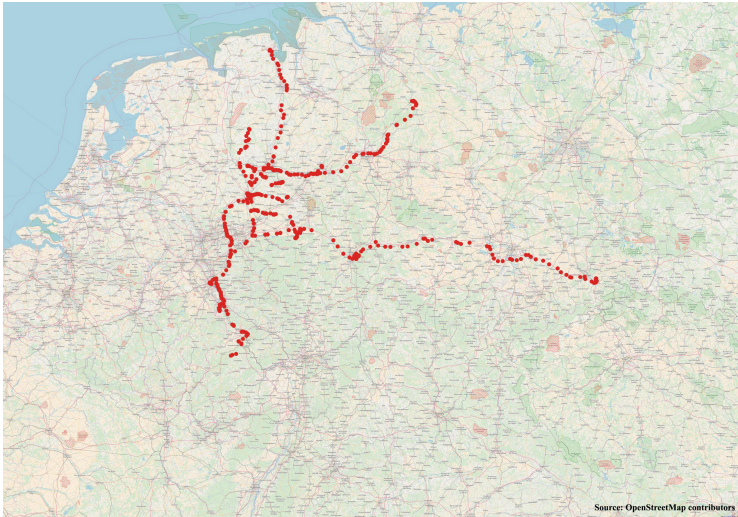


Fig. 5. Route 3 (Dormitory-Hometown) Route choices

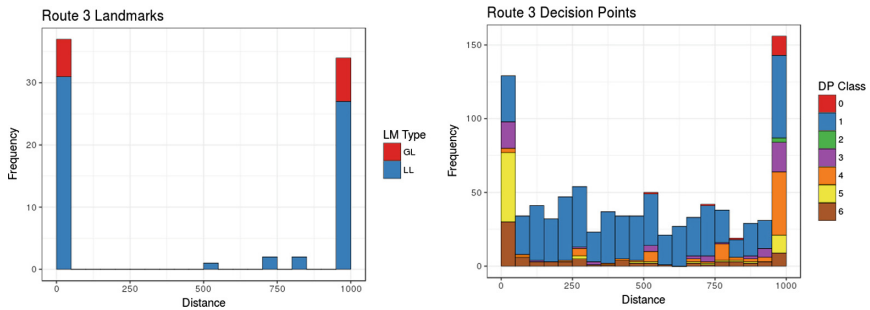


Fig. 6. Histogram of distribution of landmarks and Decision points (Route 3).

4 Discussion

Local landmarks, either situated along the route or at decision points, have been commonly used in giving route instructions. It further confirms what Raubal and Winter [13] highlighted in their study on the importance of providing local landmarks in wayfinding instructions that these should be included in route instructions focusing on the visual, sematic and structural elements.

Where are landmarks concentrated in wayfinding instructions? Many studies have investigated the importance of landmarks at decision points where an action is taken [4, 19, 20]. This was evident in the data as in the different classes of decision points showing concentration of landmarks. In Allen’s [1] study, it showed that more landmarks should be mentioned at the end of the verbal route instructions. Also, Brosset et al.’s [25] study suggested that the distribution of landmarks increases when getting

near the end of the route as well as with reference to metrics in natural environment. This is also evident in our study. But it should be considered that there are differences of the overall distribution of landmarks for the three routes. The structure of the city or the environment could play a role in the differences of placement of landmarks. In natural environments as what Brosset et al. [25] indicated, there are more landmarks mentioned at the end portion of the route for confirmation purposes. However, within the city where there is more presence of landmarks, there is unvarying distribution of landmarks in all parts of the route. Based on what Lovelace et al. [22] emphasized in their study, there could be more landmarks in the beginning or at the end part of the route which depends on the type of the environment. Hence, it is not always the case that more landmarks are located at the end part of the route.

The study shows that the intercity route does not result in the use of many landmarks compared to the other shorter routes. This suggests that the number of landmarks to be included does not depend on the route length. It is possible that when routes involve crossing many cities where there are not a lot of decision points and when not many things are happening along the way, there are not many landmarks included in the sketch maps unless the class 'straight on'. In this case, highway exits are the most important features that participants highlighted. This is mostly evident in longer route. When the route is nearing the destination, more landmarks are drawn. Route 2 showed more landmarks drawn compared to other routes. This route is from one district passing through the city center. This might be that since many shops can be considered landmarks here, participants try to select those that they think are more prominent when a change of action is required. Landmarks were well distributed with beginning and end having the highest concentration. Interestingly, there is also much concentration of landmarks in the middle part of the route, where the city center with many possible landmarks is. This suggests that when crossing the region, participants tend to recognize the importance of including landmarks for orientation purposes. Similar to Route 3, there are many landmarks also drawn when nearing the goal which is to also orient the person. But also participants have frequently included landmarks at the beginning of the route. Route 1, although short route, also showed a similar pattern with the other routes with more landmarks indicated at the end part of the route. Similar to Route 2, as this route goes inside the city center, participants drew many landmarks along the way especially when an action is indicated. Route 2 and Route 3 tend to orient the participant at the beginning of the route by always referring to landmarks which guides the wayfinder of the route direction to take.

Regarding the characteristics of the routes, the most common routes for Route 1 and Route 2 followed are one with less number of turns. The route frequently chosen by participants supports Dalton's [28] study that people follow a straight route with less angular deviations. The data also show the presence of global (off-route and distant) landmarks for orientation purposes referring to a prominent feature as a reference point [23] which serve as confirming information that the person is travelling on the right path.

5 Conclusion and Outlook

Human-generated instructions contain many landmarks. Several studies have been conducted to analyze the different landmarks mentioned in spatial descriptions mostly focusing on local landmarks. The placement of landmarks in the route instruction is also worth investigating. Reasons could be that of confirmation information, orientation and reorientation, or directional purpose. It shows that the longer the route segment does not necessarily mean more landmarks to be mentioned, although it showed more landmarks near the end portion of the route. This depends also on the availability of landmarks and when there is presence of decision points. It is important to point out that we only considered landmarks mentioned in the form of sketch map. To provide a more comprehensive understanding, the results of landmarks used in sketch map should be cross-evaluated with those used in verbal descriptions. Furthermore, we have identified the use of global landmarks in the collected data. To adhere to the theoretical framework in our analyses, we only examined the local landmarks. For future work, we will look at both local and global landmarks in the route instructions in both forms of cognitive maps and verbal descriptions. This outcome can benefit researchers who work on automatic generation of landmarks for a specific route which will be useful for navigation.

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References

1. Allen, G.: Principles and practices for communicating route knowledge. *Appl. Cognit. Psychol.* **14**(4), 333–359 (2000)
2. Kuipers, B.: The “map in the head” metaphor. *Environ. Behav.* **14**(2), 202–220 (1982)
3. Sorrows, M.E., Hirtle, S.C.: The nature of landmarks for real and electronic spaces. In: Freksa, C., Mark, D.M. (eds.) *COSIT 1999. LNCS*, vol. 1661, pp. 37–50. Springer, Heidelberg (1999). https://doi.org/10.1007/3-540-48384-5_3
4. Denis, M.: The description of routes: a cognitive approach to the production of spatial discourse. *Cahiers de psychol. cognit.* **16**(4), 409–458 (1997)
5. Timpf, S.: Ontologies of wayfinding: a traveler’s perspective. *Netw. Spat. Econ.* **2**(1), 9–33 (2002)
6. Wiener, J., Büchner, S., Hölscher, C.: Towards a taxonomy of wayfinding tasks: a knowledge-based approach. *Spat. Cognit. Comput. Interdiscip. J.* **9**, 152–165 (2009)
7. Raubal, M., Egenhofer, M.: Comparing the complexity of wayfinding tasks in built environments. *Environ. Plann. B* **25**, 895–914 (1998)
8. Nothegger, C., Winter, S., Raubal, M.: Selection of salient features for route directions. *Spat. Cognit. Comput. Interdiscip. J.* **4**(2), 113–136 (2009)
9. Winter, S.: Route adaptive selection of salient features. In: Kuhn, W., Worboys, M.F., Timpf, S. (eds.) *COSIT 2003. LNCS*, vol. 2825, pp. 349–361. Springer, Heidelberg (2003). https://doi.org/10.1007/978-3-540-39923-0_23

10. Klippel, A., Winter, S.: Structural salience of landmarks for route directions. In: Cohn, A.G., Mark, D.M. (eds.) COSIT 2005. LNCS, vol. 3693, pp. 347–362. Springer, Heidelberg (2005). https://doi.org/10.1007/11556114_22
11. Schroder, C., Mackaness, W., Gittings, B.: Giving the ‘right’ route directions: the requirements for pedestrian navigation systems. *Trans. GIS* **15**(3), 419–438 (2011)
12. Dale, R., Geldof, S., Prost, J.-P.: Generating more natural route descriptions. In: Proceedings of the 2002 Australasian, pp. 41–48 (2002)
13. Raubal, M., Winter, S.: Enriching wayfinding instructions with local landmarks. In: Egenhofer, M.J., Mark, D.M. (eds.) GIScience 2002. LNCS, vol. 2478, pp. 243–259. Springer, Heidelberg (2002). https://doi.org/10.1007/3-540-45799-2_17
14. Elias, B.: Determination of landmarks and reliability criteria for landmarks (2003)
15. Tom, A., Denis, M.: Referring to landmark or street information in route directions: what difference does it make? In: Kuhn, W., Worboys, M.F., Timpf, S. (eds.) COSIT 2003. LNCS, vol. 2825, pp. 362–374. Springer, Heidelberg (2003). https://doi.org/10.1007/978-3-540-39923-0_24
16. Rehrl, K., Leitinger, S., Gartner, G., Ortig, F.: An analysis of direction and motion concepts in verbal descriptions of route choices. In: Hornsby, K.S., Claramunt, C., Denis, M., Ligozat, G. (eds.) COSIT 2009. LNCS, vol. 5756, pp. 471–488. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-03832-7_29
17. Jackson, P.: In search of better route guidance instructions. *Ergonomics* **41**(7), 1000–1013 (1998)
18. Meilinger, T., Knauff, M.: Ask for directions or use a map: a field experiment on spatial orientation and wayfinding in an urban environment. *Spat. Sci.* **53**(2), 13–23 (2008)
19. Denis, M., Pazzaglia, F., Cornoldi, C., Bertolo, L.: Spatial discourse and navigation: an analysis of route directions in the city of Venice. *Appl. Cognit. Psychol.* **13**(2), 145–174 (1999)
20. Michon, P.-E., Denis, M.: When and why are visual landmarks used in giving directions? In: Montello, D.R. (ed.) COSIT 2001. LNCS, vol. 2205, pp. 292–305. Springer, Heidelberg (2001). https://doi.org/10.1007/3-540-45424-1_20
21. Brosset, D., Claramunt, C., Saux, E.: A location and action-based model for route descriptions. In: Fonseca, F., Rodríguez, M.A., Levashkin, S. (eds.) GeoS 2007. LNCS, vol. 4853, pp. 146–159. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-76876-0_10
22. Lovelace, K.L., Hegarty, M., Montello, D.R.: Elements of good route directions in familiar and unfamiliar environments. In: Freksa, C., Mark, D.M. (eds.) COSIT 1999. LNCS, vol. 1661, pp. 65–82. Springer, Heidelberg (1999). https://doi.org/10.1007/3-540-48384-5_5
23. Sadalla, E., Burroughs, W., Staplin, L.: Reference points in spatial cognition. *J. Exp. Psychol. Hum. Learn. Mem.* **6**(5), 516–528 (1980)
24. Allen, G.L.: From knowledge to words to wayfinding: issues in the production and comprehension of route directions. In: Hirtle, S.C., Frank, A.U. (eds.) COSIT 1997. LNCS, vol. 1329, pp. 363–372. Springer, Heidelberg (1997). https://doi.org/10.1007/3-540-63623-4_61
25. Brosset, D., Claramunt, C., Saux, E.: Wayfinding in natural and urban environments: a comparative study. *Cartographica* **43**(1), 21–30 (2008)
26. Schwering, A., Li, R., Anacta, V.: orientation information in different forms of route instructions. In: Danny Vandenbroucke, B. (ed.) Proceedings on The 16th AGILE International Conference on Geographic Information Science (2013)
27. Winter, S.: Communication about space. *Trans. GIS, Guest Editor.* **8**(3), 291–296 (2004)
28. Dalton, R.: The secret is to follow your nose: route path selection and angularity. *Environ. Behav.* **35**(1), 107–131 (2003)

29. Elias, B.: Extracting landmarks with data mining methods. In: Kuhn, W., Worboys, M.F., Timpf, S. (eds.) COSIT 2003. LNCS, vol. 2825, pp. 375–389. Springer, Heidelberg (2003). https://doi.org/10.1007/978-3-540-39923-0_25
30. Dräger, M., Koller, A.: Generation of landmark-based navigation instructions from open-source data. In: Proceedings of the 13th Conference of the European Chapter of the Association for Computational Linguistics, Stroudsburg, PA, USA, pp. 757–766 (2012)
31. Rousell, A., Hahmann, S., Bakillah, M., Mobasheri, A.: Extraction of landmarks from OpenStreetMap for use in navigational instructions. In: Proceedings of the 18th AGILE Conference on Geographic Information Science, Lisbon, Portugal (2015)
32. Duckham, M., Winter, S., Robinson, M.: Including landmarks in routing instructions. *J. Locat. Based Serv.* **4**(1), 28–52 (2010)