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"Landmark Route": A Comparison to the Shortest Route

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Abstract. Most navigation systems for pedestrians output the shortest route. However, there are findings that travellers do not use the shortest route when free to choose. One alternative to minimising spatial distance is the incorporation of landmark information in a shortest route algorithm. Yet, we do not know whether pedestrians prefer such a landmark route over the shortest route. Therefore, we perform a survey and show participants videos of a shortest and a landmark route. We let participants answer questions concerning navigation satisfaction, route communication, and route comparison. Our findings show that the landmark route is more favourable.

Keywords. Spatial Cognition, Navigation, Wayfinding, Landmark Route, Shortest Route

1 Introduction

Most navigation systems for pedestrians output the shortest route. However, Lima et al. (2016) find that a significant fraction of drivers' routes are not optimal regarding the cost minimisation assumption. Furthermore, Zhu and Levinson (2015) state that most travellers do not use the shortest route and clearly have other preferences when choosing their routes. Rodríguez et al. (2015) show that other factors such as the presence of a greenway or trail, higher safety, or presence of sidewalks are positively associated with the route choice of pedestrians. It is a known fact that travellers prefer route descriptions enriched with landmarks (Lynch, 1960; Allen, 2000; Fontaine and Denis, 1999; Tversky and Lee, 1999; Tom and Denis, 2003; Michon and Denis, 2001). Based on these considerations, Nuhn and Timpf (2021) propose to generate a landmark route by incorporating landmark information as an alternative to spatial distances in a shortest route algorithm. However, the generation of such alternative routes requires a number of different input data and preprocessing steps, before a routing algorithm can be applied. The generation of a landmark route such as in Nuhn and Timpf (2021) needs the visual, semantic, and structural attributes (Sorrows and Hirtle, 1999) of a geographic object at the street intersections of a street network as input. Furthermore, it requires an approach to identify landmarks among the objects, and finally, the algorithm to find an optimal route. In contrast, the shortest route operates on a simple graph structure and requires only distance information as weights on edges.

Currently, we do not know whether an additional data collection and pre-processing effort would be justified. We also do not know whether humans even notice differences between the navigation along a route generated with landmark weights and a conventional shortest route. Therefore, after a review of related work (Section 2), we investigate navigation satisfaction, route communication, and comparison between a shortest and a landmark route in the framework of a survey (Section 3). We discuss the results (Section 4) and the hypothesis that the landmark route is more favourable in terms of navigation satisfaction, route communication, and route comparison (Section 5). We conclude with an outlook on future work (Section 6).

2 Related Work

This section provides an overview of the definition and characterisation of landmarks (Section 2.1). Subsequently, we investigate the generation of routes with the help of landmarks (Section 2.2).

2.1 Definition and Characterisation of Landmarks

There are numerous definitions of landmarks available and a satisfactory one is somewhat elusive (Presson and Montello, 1988). Lynch (1960) gives the first definition and defines landmarks as point references, which are external to an observer. He defines landmarks as simply physical elements, which can vary in scale such as buildings, signs, stores, mountains, or other geographic objects. The property that turns a conventional geographic object into a landmark is known as landmark salience (Raubal and Winter, 2002; Elias, 2003). There are three widely accepted key characteristics of an object that influence salience: visual, structural, and semantic salience (Sorrows and Hirtle, 1999; Raubal and Winter, 2002).

However, these categories are not mutually exclusive (Duckham et al., 2010) and there are other dimensions influencing an object's salience. For example personal dimensions such as personal background, personal interests, or prior spatial knowledge (Nuhn and Timpf, 2017). Additionally, whether an object becomes a landmark depends not only on the object itself but also on the perspective of the observer, and the other geographic objects in the environment (Caduff and Timpf, 2008). Presson and Montello (1988) even state that everything standing out might become a landmark.

2.2 Route Generation Algorithms and Landmarks

A number of approaches to consider landmarks in route generation algorithms are developed in the past years. Caduff and Timpf (2005a, b) propose the landmark-spider algorithm that generates the clearest route in terms of spatial references and uses landmarks to give route descriptions. The landmarks are selected considering the direction and distance between geographical objects and the traveller and additionally, the salience of the objects. Rüetschi et al. (2006) use landmarks as parts of route descriptions and map these instructions to sets of edges in a route network. In order to find an optimal route they build an auxiliary graph and use a standard shortest route algorithm. Duckham et al. (2010) develop an algorithm for generating routing instructions with references to landmarks. The algorithm depends solely on commonly available data (to the time the paper was published). This idea is also pursued by Rousell and Zipf (2017). They propose a prototype navigation service that extracts landmarks based on several metrics. They show that suitable landmarks can be extracted from publicly available OSM (OpenStreetMap) data and integrated in route directions.

A number of approaches use a modified Dijkstra's algorithm (Dijkstra, 1959). Elias and Sester (2006) adapt weights according to the uniqueness and usefulness of location of a landmark as well as its visibility, permanence, and brevity of the description. These weights are assigned to the edges of a graph and an optimal route is calculated. Chandrasekara et al. (2016) calculate the strength of a landmark by considering landmark density along an edge as well as its salience. The salience is calculated based on parameters such as height, visibility, and social/cultural salience. They integrate both the distance of the route and the strength of the landmark in a route planning model.

Nuhn and Timpf (2021) propose a weighting method, which is integrated in Dijkstra's algorithm (Dijkstra, 1959) to generate a landmark route. The weights are calculated from the sum of the visual, semantic, and structural salience of a landmark (Raubal and Winter, 2002; Sorrows and Hirtle, 1999). The higher the salience of a landmark the higher the landmark weights for an edge in the routing graph. Since Dijkstra's algorithm is optimized on minimising the weights of an edge, Nuhn and Timpf (2021) adjust the weights, resulting in a very high weight for an edge in the routing graph with no suitable landmark. This prevents the algorithm in considering such an edge while generating the route. Nuhn and Timpf (2021) compare the landmark routes with the corresponding shortest routes and show that the extra distance and time needed to walk the landmark routes is acceptable for most of the routes. Nuhn and Timpf (2022) did the first investigations to find out whether humans prefer a landmark route over a shortest route. Although they find that the participants were more satisfied with the shortest route, there were hints that route choice depends on environmental parameters. Additionally, route length had an impact on navigation satisfaction (Nuhn and Timpf, 2022). Thus, in this study, we avoid negative effects, such as different lengths and environments of the routes (Section 3.1), and investigate again whether humans prefer a landmark route over a shortest route.

3 Survey

Our aim is to find out whether participants prefer a landmark over a shortest route. We use a survey for this study, since it can make use of qualitative research methods such as free-text questions (e.g. for route descriptions) and quantitative research methods such as questionnaires with numerically rated items (e.g. to rate routes) (Ponto, 2015). In addition to the survey we use experimenters who guide the participants through the procedure. Survey participants can ask the experimenters e.g., for clarifications on unclear questions (Ball, 2019). The survey was prepared in the fall of 2020 and carried out from Feb 8th to March 31st, 2021 (i.e. during the pandemic, therefore, a digital survey was necessary). Section 3.1 gives an overview on the routes we use and Section 3.2 introduces the procedure of the survey. In Section 3.3 we give a note on the data and software availability for this paper.

3.1 Shortest Route and Landmark Route

At the time of the selection of our route a methodological framework according to predefined weighted criteria such as in Mazurkiewicz et al. (2020) was still unpublished. We therefore selected our routes according to the findings in Nuhn and Timpf (2022) and the following criteria:

1. nearly identical lengths, in order to eliminate the length of the route as a potential influencing factor, and

2. similar environments around the routes, in order to avoid different travel experiences (positive or negative) on one of the routes.

Nuhn and Timpf (2021) thoroughly evaluate and compare landmark routes to the corresponding shortest routes. Fig. 1 shows a landmark and a shortest route with only 34

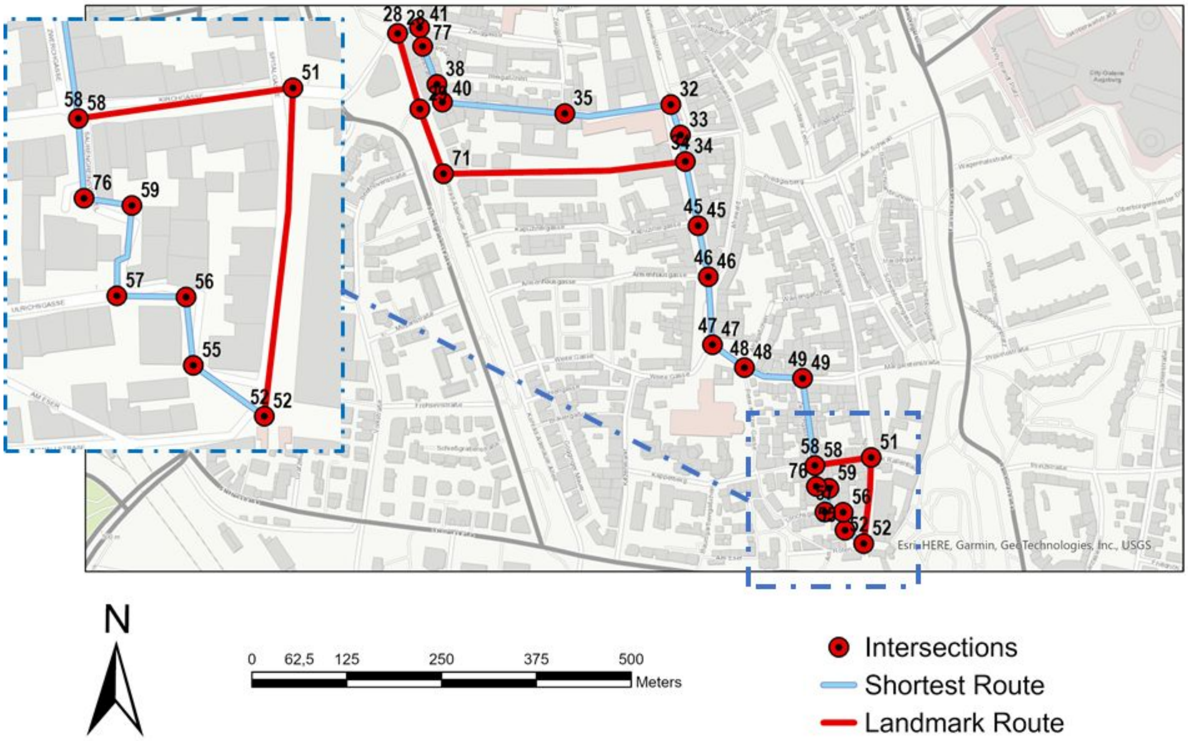

Figure 1. Landmark route and shortest route (taken from Nuhn and Timpf (2021)).

meters difference in length. Both routes run through similar environments. First, they run independently through streets with high architecturally attractive buildings. Then, they meet and pass shops and restaurants, before they split again. They run both through alleys with smaller buildings until they finally reach the destination. The routes show a high difference in the number of street intersections - while the shortest route has 21 street intersections the landmark route passes only 12. The landmark route "might be favourable because it requires fewer actions, is more eminent in terms of landmarkness, and takes only 24 seconds longer to walk" (Nuhn and Timpf, 2021, p.16). Consequently, for our survey, we utilised the routes given in Fig. 1.

3.2 Procedure

The survey was established in the framework of a lecture at the university called "Modelling the perception of landmarks". The participating students acted as experimenters. Each participant was contacted individually and an individual appointment was arranged. The survey took place during the COVID-19 pandemic. Thus, we applied a digital survey, since most of the survey participants were not able to participate on-site. 37 people participated in the survey, 24 of whom were females. Amongst them were people with different educational backgrounds. The average age of the participants was 32.59 years (min = 20, max = 79, std = 15.63). 14 of the participants lived in Augsburg. During the survey, that took place via video telephony, we first introduced the participants to the procedure and asked them to give their consent for the experiment. We applied a "within-subject" design meaning that each participant was exposed to both, the shortest and the landmark route (Charness et al., 2012). However, we varied the order of the routes and started alternately with the shortest or the landmark route. We used ESRIs Survey123 for the questionnaires, a tool to create and publish surveys (Survey123, 2021).

In the first step, the participants completed a background questionnaire, which included questions concerning age, gender, country of residence, country of birth, education, and personal interests (such as interest in shopping or historical monuments). Furthermore, participants stated whether they lived in the city and, in case they answered affirmative, how long they lived there. Then, the participants watched a video of the first route (either shortest or landmark, dependent on the order of the routes). Since the participants only watched videos no instructions were given to walk along the route. Subsequently, the participants completed a questionnaire regarding navigation satisfaction. It included questions about the perceived difficulty and easiness of navigation, the participants' satisfaction with the route, the satisfaction with the landmarks shown, and the perceived duration and distance of the route. Furthermore, we asked participants whether they have walked the whole route or parts of the route. Additionally, the participants had to give a route description to test route communication. The survey participants repeated the whole procedure for the second route. Afterwards, the participants answered a questionnaire regarding route comparison of the shortest and the landmark route. This questionnaire included comparative questions about the descriptions, the likeability, and the satisfaction with the routes, as well as comparative questions regarding the landmarks along the route. Finally, the participants chose the route they would prefer in case they would have to walk from the start to the destination.

The survey was completed on average in 61 minutes (min = 30, max = 120, std = 21.77). At the end of the experiment the experimenters thanked the participants for taking part in the experiment and reminded them to keep the procedure confidential.

3.3 Data and Software Availability Section

The survey was answered anonymously in the Survey123 App (Survey123, 2021). The result of the survey is a downloadable .csv-file. All statistical analyses, which results are detailed in the following section, have been performed in OpenOffice 4.1.11. Survey data in CSV format that includes the full demographic information and responses from each participant, geographic data in shapefile format with the two routes presented to the participants, and a spreadsheet in ODS format that was used to calculate the hypotheses tests for differences in responses are available on figshare and are accessible via the following DOI: https://doi.org/10.6084/m9.figshare.19794289. The two videos (one per route) in MP4 format that were shown to the participants are not shared publicly because of privacy reasons. They are available from the corresponding author on request.

The workflow underlying this paper was partially reproduced by an independent reviewer during the AGILE reproducibility review and a reproducibility report was published at https://doi.org/10.17605/osf.io/94VNX.

4 Results of the Survey

This section presents the results of the survey. We use an unpaired two-tailed t-test to compare the results for the shortest and the landmark route. As soon as the level of significance is smaller than 5% ($\alpha < 0.05$) we consider the results as statistically significantly different. We investigate the results of the questionnaires concerning navigation satisfaction (Section 4.1), route communication (Section 4.2), and route comparison (Section 4.3) in the following subsections.

4.1 Navigation Satisfaction

We investigate the prior spatial knowledge regarding the routes of the participants. Only three people have walked the whole shortest route before (Table 1) and fourteen participants have never walked the shortest route. Most of the participants have walked parts of the route before. Six of the participants have walked the landmark route before, 12 participants have never walked the landmark route before, and 19 have walked parts of the route.

Table 1. Prior Spatial Knowledge of the Route.

	Shortest Route	Landmark Route
Yes	3	6
No	14	12
Parts of the Route	20	19

The perceived time of the video of the shortest route ranges around 14.32 minutes (min = 5, max = 30, std = 5.10). The real time of the video of the shortest route is 12.43 minutes. We find a significant difference between the real time of the video of the shortest route and the perceived time ($p = 0.027$). The difference between the perceived and the real time of the video of the landmark route (12.83 minutes) is not statistically significant ($p = 0.059$). The average for the perceived video time is 15.08 minutes (min = 7, max = 45, std = 7.14).

The length of the shortest route is 1162 meters. The perceived average length is 1665 (min = 800, max = 3000, std = 665.89). The length of the landmark route is 1196 and the perceived length is on average 1668 meters (min = 800, max = 4000, std= 727.04). Both differences between the real and the perceived length are extremely statistically significant.

Finally, we investigate the answers for the five questions concerning navigation satisfaction:

Q1: How easy do you think it is to walk the route?

Q2: How satisfied are you with the number of turns?

Q3: How did you like the landmarks shown?

Q4: How difficult do you think it is to find the way back without assistance?

Q5: Would you be able to find the way back without assistance/resources?

The answers are rated on four point Likert-Scales (e.g. for satisfaction: very (1), fairly (2), not very (3), and not at all (4)). We observe a statistically significant difference for Q1 and Q2 (Table 2).

4.2 Route Communication

We investigate the route descriptions of the participants in order to test route communication and asked them to describe the route (Q: Describe the route to someone else on the street.) We compare the number of words per street intersection, since the shortest route includes nine street

Table 2. Results Navigation Satisfaction.

Route	Measure	Q1	Q2	Q3	Q4	Q5
Shortest	Mean	2.59	2.68	2.22	2.70	2.24
	Std	0.80	0.88	0.79	0.88	1.06
Landmark	Mean	1.76	1.97	1.97	2.27	1.78
	Std	0.64	0.90	0.60	0.99	0.98
Comparison shortest/landmark route	p-Value	0.000	0.001	0.139	0.051	0.057

Table 3. Results Route Communication (i = intersection, p = participant).

Elements	SR	$\varnothing_i$	$\varnothing_p$	LR	$\varnothing_i$	$\varnothing_p$	p-Value
Words	2841	135.29	3.66	2599	216.58	5.85	0.000
3D-Landmarks	158	7.52	0.20	124	10.33	0.28	0.054
2D-Landmarks	107	5.10	0.14	89	7.42	0.20	0.019
Actions	252	12	0.32	230	19.17	0.52	0.000
Distance	4	0.19	0.01	11	0.92	0.02	0.052
Street names	40	1.90	0.05	48	4	0.11	0.031

intersections more. The route descriptions vary considerably in the number of words used. The average number of words used by the survey participants is 3.66 words per street intersection to describe the shortest route and on average 5.85 words per street intersection for the landmark route (Table 3). This difference is extremely statistically significant.

We also compare the number of elements per street intersection and per participant, because of the lower number of street intersections of the landmark route (Table 3). We investigate actions, which are propositions "prescribing an action without referring to a landmark" (Daniel and Denis, 1998, p.47). Following Michon and Denis (2001) we classified the landmarks in the route descriptions in 2D-landmarks such as streets, squares, or tramlines, and, 3D-landmarks, such as buildings, statues, or fountains. Furthermore, we investigate how many times street names and distance information are mentioned. There are more 2D-Landmarks, actions, and street names included in the landmark than in the shortest route descriptions.

4.3 Route Comparison

The last questionnaire concerns the comparison of the shortest with the landmark route:

Q1: Which route did you like more?

Q2: On which route did you like the landmarks better?

Q3: Which route did you find easier to describe?

Q4: Which route would you prefer to walk if you had to walk from the start to the destination?

Most of the participants like more the landmark route (Table 4) and most of them like the landmarks more on the landmark route. Additionally, 30 participants find that the landmark route is easier to describe and 21 prefer the landmark route in case they have to walk from the starting point to the destination.

Table 4. Results Route Comparison.

Elements	Shortest Route	Landmark Route
More likeable	14	23
Better landmarks	13	24
Easier to describe	7	30
Preference	16	21

5 Discussion

We hypothesise that the landmark route is more favourable than the shortest route. In the following we discuss the results of the survey with regard to this hypothesis focusing on navigation satisfaction (Section 5.1), route communication (Section 5.2), and route comparison (Section 5.3).

5.1 Navigation Satisfaction

The first questions of the navigation satisfaction questionnaire deal with the perceived distance and time of the routes. An important factor affecting a travellers willingness to take a detour is the additional time needed for this detour (Kröller et al., 2021). Thus, we can assume that in case a route is perceived as too time-consuming, travellers could become exhausted and unwilling to walk it. We find a statistically significant difference between the time of the video and the perceived time for the shortest route. The participants perceive it on average more than two minutes longer than it actually really is. It is a well known fact that stimulus motion can lengthen the perceived time (Brown, 1995). Furthermore, we know that changes in speed in stimuli can affect the perception of duration (Matthews, 2011). However, such a difference can not be found for the landmark route. Based on this we can assume that people may have found the landmark route less time-consuming than the shortest route.

The differences between the length of the routes and the perceived length are statistically significantly different. This applies for both settings. The participants think that the shortest route is around 43% longer and the landmark route 39% longer than it really is. Generally, the estimation of the distance was very difficult for the survey participants, as they did not physically walk the routes. This might bias the results, as the participants only watched videos.

Next, we investigate whether there are differences between the results of the landmark and the shortest route for the five questions concerning navigation satisfaction (Table 2). For Q1 we observe a statistically significant difference, suggesting that the participants think that the landmark route is easier to walk. One reason for this can be found in the route itself. The first part of the shortest route already shows a higher number of street intersections. Additionally, the last part of the shortest route runs through winding streets. Both facts might result in more difficulties while walking.

The difference for Q2 is also statistically significant. Obviously, the participants are not as satisfied with the number of turns on the shortest route than on the landmark route. The shortest route has 21 street intersections in total - nine street intersections more than the landmark route. This fact contributes to a higher preference for the landmark route and is in consistence with the finding that least directional change is a key determinant of route choice (Shatu et al., 2019).

We do not observe a statistically significant difference for Q3. In both settings the participants say that they do "somewhat" like the landmarks. This means none of the landmarks and thus, none of the environments of the routes, is perceived better or worse (compare our criterion for route selection in Section 3.1).

The participants think that the difficulty to reverse the route without assistance (Q4) is more difficult for the shortest route than for the landmark route. However, this difference is not statistically significant.

The difference for Q5 also does not reach statistical significance (Table 2). However, the absolute values show a tendency for the landmark route to be easier to walk back without assistance/resources. Generally, Q4 and Q5 seem to be difficult to judge, since the participants only watched videos and did not really reverse the route.

5.2 Route Communication

The participants use more words per street intersection to describe the landmark route. Some descriptions only include the main points such as: "straight along the train stop, turn left, turn right, turn left at the church, turn right, turn left until you reach the old city gate" while others consist of complete sentences including detailed descriptions. This finding is in line with the study of Tversky and Lee (1999), who report that some participants even create only lists as descriptions. We observe that people with no knowledge about the route (Table 1) use more words for the description of the landmark route than people who have already walked parts of the routes. We assume that they need more words to describe things than people who know e.g., a name for a landmark.

We expect, that the landmarks along the landmark route are more outstanding, and thus, occur more in the route descriptions. The participants use some more 3D-landmarks per intersection to describe the landmark route (Table 3), however this difference is not statistically significant. Surprisingly, they use more 2D-landmarks in the description of the landmark route, which is unexpected, since the algorithm does not consider these landmarks. However, it seems that these landmarks are important elements for route communication. Especially, for participants who have no knowledge of the landmark route, since they use more often 2D-landmarks than participants who have only walked parts of the route before.

The participants use more actions per street intersection to describe the landmark route. This is unexpected since the last part of the shortest route runs through small winding streets which would need more actions to describe them. However, a detailed analysis of the route descriptions shows that the participants tend to summarise this part of the route with just referring to "a maze of little alleys", "several small turns", or "a number of small streets". We observe this behaviour particularly for familiar people who use significantly less actions to describe the shortest route than the landmark route.

We observe that familiar people use more street names for both routes than participants who have never walked the routes. Additionally, participants who are familiar with parts of the routes use more street names than people with no knowledge (Table 1). We assume that this difference may stem from experience, familiar people may remember more street names, because they have walked the route in the past. It is a common occurrence that familiar participants are able to remember more, e.g., Lovelace et al. (1999) observe this behaviour for landmarks. This is also consistent with the observation that participants who are familiar with the shortest route use less actions than people who have never walked the route before. It seems plausible because familiar people are able to refer simply to street names while unfamiliar people need more references to actions to describe the turns to be made at a street intersection.

5.3 Route Comparison

Table 4 shows that 24 participants like the landmarks better on the landmark route. This is in contrast to Q3 of the navigation satisfaction questionnaire (Section 5.1), where we do not find a preference for the landmarks on any of the routes. However, for the question in the route comparison questionnaire participants had to decide for one of the routes. Table 4 shows that 30 participants state that they find the landmark route easier to describe. This is in line with Q1 and Q2 of the navigation satisfaction questionnaire, where the participants expect the landmark route to be easier and are more satisfied with the number of turns in it. Since the landmark route really shows a lower number of turns, this might have given the participants the feeling that it would be easier to describe. More than half of the participants (21, Table 4) prefer the landmark route in case they would have to walk from the starting point to the destination. This emphasises the conclusion that we have drawn from the finding that we do not find a statistically significant difference between the perceived and the real time of the video of the landmark route. It thus underlines the conclusion that people may find the landmark route less exhausting than the shortest route.

6 Conclusion and Future Work

In this study we investigate the hypothesis whether participants prefer a landmark over a shortest route. Therefore, we investigate navigation satisfaction with both routes and compare them with the help of a survey. We find that the shortest route is estimated longer in time when it really is, while the landmark route is not. Thus, we can assume that people may find the landmark route less exhausting and might be more willing to walk it. Both differences of the real and the perceived length of the routes are reported to be extremely statistically significant. However, this might be due to the fact that people only watched videos of the routes and it is hard to assess how long the routes are in reality.

Overall the landmark route performs better than the shortest route. The participants think that it is easier to walk and are more satisfied with the number of turns on the landmark route. They equally like the landmarks on both routes, giving us hints that the environments around the routes are perceived as identical by the participants during the survey.

The results for the route comparison undermine the preference for the landmark route. The participants like it more, like the landmarks better on the route, find it easier to describe and have a general preference for it, in case they would have to walk from the starting point to the destination. Thus, we can confirm our hypothesis that the landmark route is more favourable in terms of navigation satisfaction and route comparison.

In this work we choose two routes nearly identical in length and running through similar environments. We suggest that future work concentrate on considering these points directly in the route generation algorithm. Thus, the algorithm proposed by Nuhn and Timpf (2021), which is based on landmark weights, should additionally consider the length of the routes and factors, which map the environments of the route. This might for example be semantic attributes describing whether the route runs through office buildings or smaller more convenient areas, with cafes, restaurants, and shops. These attributes can be directly integrated in the landmark weights and then, attached to the edges of the route network.

A major point of future work will be a survey with participants in a real world scenario. Currently we are not able to do surveys on-site due to the COVID-19 pandemic. However, as soon as it is possible we plan to investigate whether we can confirm the findings for the preference of the landmark route in an on-site setting. We assume that there is a bias introduced by experiencing the route through a video instead of walking it. As we noticed the real and the perceived length of the routes are statistically significantly different. This observation might be the result of only watching videos. We assume that participants who are walking the routes might be better able to judge their length. Another source of bias might be an unstable camera work, which can e.g. lead to more perceived turns. Another drawback of only watching videos is that some task are not possible, such as route reversal tasks. Finally, the ability to look around during navigating is not possible. Thus, we hope that we can eliminate the disadvantages of only watching videos with surveys on-site.

Another possibility, besides surveys on-site, would be the use of a 3D virtual reality environment. The participants could virtually walk along two routes. The first route with no landmarks and only following the itinerary. The second route could include landmarks. This possibility might be an alternative to on-site settings helping to compare the landmark and the shortest route.

In this survey we investigated two routes. We chose them considering the criteria in Section 3. However, more than just two routes could be considered in the survey. The routes could be either varied between the survey participants or participants could walk more than these two routes. This might also help in eliminating environmental biases such as different travel experiences, different length of the routes, or different numbers of intersections. Thus, further investigations should focus on this idea and investigate the outcomes.

In order to conclude, we note that participants prefer the landmark route. However, the generation of a landmark route requires the collection of additional input data and has more preprocessing steps than the generation of a shortest route. Thus, in case future work confirms our finding we need to find methods to support this process in order to make it as smooth as possible.

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