# Developing an Open Pedestrian Landmark Navigation Model

Anita Graser
AIT Austrian Institute of Technology, Vienna, Austria

**Abstract**

Today's publicly available pedestrian navigation systems still use paradigms developed for car navigation. In this paper, we present a novel landmark-based pedestrian navigation model using open source tools and open data from OpenStreetMap, which is available globally and free of charge. This approach ensures that our landmark navigation model is widely applicable, rather than restricted to a certain area with exceptional data sources. Our contributions cover algorithms for extraction, weighing, and selection of landmarks based on their suitability, as well as the generation of landmark-based navigation instructions for a given pedestrian route. The system has been implemented using PostGIS as a data store and QGIS for algorithm development. First field tests with pedestrians show promising results by confirming that our weighted landmark selection outperforms a simple baseline approach by reducing the number of navigation errors and revealed future challenges for the generation of intuitive pedestrian navigation instructions.

**Keywords**

landmarks, navigation, wayfinding, pedestrians, OpenStreetMap

## 1 Introduction

When it comes to wayfinding and navigation, pedestrians have different needs than vehicle drivers. They are allowed to use infrastructure forbidden to cars and they do not follow clearly defined linear routes. Furthermore, spatial cognition research has shown that humans need salient objects called landmarks for orientation and navigation. Landmarks serve as reference points in the environment, which help to structure space and support navigation by identifying points, where navigational decisions have to be made (Millonig & Schechtner 2007). Including landmarks into navigational instructions has been shown to improve pedestrian navigation systems (Ross et al. 2004). Since manual curation of landmark databases is time-consuming and thus expensive, it is necessary to develop methods, which can extract suitable objects for pedestrian navigation instructions from available map data. For standard car navigation, it is sufficient to have access to street names and the geometry of the street network to generate turn-by-turn instructions such as ‘‘In 500 meters, turn right into Main Street”. In contrast, to allow navigation by objects, it is necessary to extract more information (Elias 2003), such as points of interest and geographical data (e.g., rivers, landscape, characteristic buildings), and connect these to the pedestrian route in meaningful ways. Two common categories of landmarks are global and local landmarks. For navigation purposes, global landmarks are used to communicate a general directional. They are typically at a distance or even off the route. Local landmarks, on the other hand, are typically used to communicate information about a certain position. They are close to the route, and can be further categorized into landmarks at decision points, landmarks at potential decision points, and on-route landmarks along segments (Lovelace et al. 1999).

The remainder of this paper is structured as follows: Section 2 provides an overview of the research in the field of landmark-based navigation. Section 3 summarizes the data requirements and preprocessing steps necessary to prepare the data for our landmark-based pedestrian navigation model. Section 4 describes the algorithms developed to generate landmark-based navigation instructions for pedestrian routes. Finally, Section 5 discusses the current status of the developments, including results from field tests and open research challenges.

## 2 Landmark-based Navigation

In order to make landmarks available for navigation applications, it is necessary to develop methods for automatically identifying appropriate landmarks. Several different approaches have been developed for this task, but the automatic extraction of these features from available geospatial datasets still remains problematic (Rousell et al. 2015). Many research projects and publications therefore use highly specific data, which is not available at a bigger scale, such as detailed campus maps with manually curated landmarks (Selvi et al. 2012), cadastral maps (Winter et al. 2008), city building databases (Elias & Sester 2002), building façade information (Raubal & Winter 2002), or digital surface model (DSM) data from laser scanning (Brenner & Elias 2003).

One simple method to detect landmarks is to extract landmarks from a building database by intersecting named buildings with the buffered route (Elias & Sester 2002). This simple method ignores actual visibility as well as the salience of the landmark, even though it could be argued that named buildings would typically be more salient that others. Improving on this approach, Elias (2003) and Winter et al. (2008) describe methods to compute landmarks uniqueness in the route environment using detailed geometry and attribute information about the specific landmark objects. Other early approaches analyze the attractiveness of landmarks at decision points based on their façades (Raubal & Winter 2002). To address the issue of landmark visibility, Brenner & Elias (2003) go as far as to suggest the use of DSM data to check the visibility of a specific object.

While research into how to select and manage (Fang et al. 2012) landmarks from information-rich highly specific databases (which provide instance-level information about the detailed visual appearance and geometry of potential landmark objects) advanced significantly in those years, landmark-based navigation outside dedicated research projects did not gain traction. As described by Duckham et al. (2010), in many cases, the detailed information required by previously developed approaches ''may be unavailable, proprietary, infrequently updated, or simply will not exist". Dräger & Koller (2012) even state that ''information about landmarks is mostly limited to geometric data and does not specify the semantic type of a landmark (such as ''church"); and updating the landmark database frequently when the real world changes (e.g., a shop closes down) remains an open issue.'' Duckham et al. (2010) therefore present an algorithm to generate route instructions with references to landmarks from commonly available category-level (instead of instance-level) information, such as Yellow Pages.

Currently, we observe two main research trends: With the emerging access to big amounts of social media data, the first trend is to look into ways to extract additional landmark information from these new sources. For example, Quesnot & Roche (2014) compute ''landmarkness" using Foursquare check-ins and Facebook likes and ''talking about". Zhu & Karimi (2015) train a neural network to select landmarks based on OpenStreetMap (OSM), DEM, Bing images, and Foursquare logins. The second observable trend is to fill in the gaps to finally bring landmark-based navigation to the end user. This research is mostly focused on using data from OSM because it is open and globally available (OpenStreetMap Wiki 2016) and contains both information about the pedestrian network as well as potential landmarks. For example, Rousell et al. (2015) work on extracting landmarks from OSM and selecting the most suitable landmark based on distance and estimated visibility.

In line with the trend to bring landmark-based navigation to the end user, our goal is to develop a landmark-based pedestrian navigation system that leverages OSM data. Our contributions, which are presented in this paper are: a flexible approach for landmark extraction and weighing, which enables a landmark selection algorithm that goes beyond Rousell et al. (2015) and takes into account different weights for different landmark categories, as well as algorithms for generating navigation instructions. The system has been developed using PostGIS (PostGIS Development Team 2016) for data storage and QGIS (QGIS Development Team 2016) for algorithm development because the QGIS API provides a routing engine, spatial analysis functions, and flexible data access solutions. Since all prerequisites are already in place, this setup makes it possible to fully focus on algorithm development.

# 3 Data Preparation for Pedestrian Landmark Navigation

To ensure that our landmark navigation model is widely applicable, rather than restricted to a certain area with exceptional data sources, we use data from OSM, which is available globally and free of charge. The following sections describe the data requirements for our landmark navigation model: the requirements for the pedestrian routing graph, the extraction of potential landmarks from OSM, and the weighing of landmark categories according to their suitability. Both routing graph and landmarks are stored in a PostGIS database, which provides flexible data handling using database views to filter and annotate features.

## 3.1 Pedestrian Routing Graph Preprocessing

To enable turn-by-turn navigation instructions, a routing graph needs to contain certain information about the road network. In most basic applications, the necessary information is limited to street geometry and name. This commonly available information makes it possible to determine locations where the user has to turn and provide classic turn-by-turn instructions that contain distances, directions, and street names. This type of turn-by-turn instructions is well known from car navigation systems.

To provide more detailed information, which is of particular relevance for pedestrians, we expand these basic graph information requirements. The following information, which is available in OSM, must be extracted for all edges in the routing graph: (1) *edge geometry* is used to determine route length, location of turns, and direction of turns; (2) *street name* is used to determine decision points based on changing road names, and describe the route in the navigation instructions; (3) *type of way* is used to provide further context in navigation instructions, in particular the following types are annotated:

- *‘‘sidewalk”* marks sidewalk edges. This information is used in instructions, which describe crossing a road from a sidewalk on one side of the road to the other. Sidewalk edges can be derived directly from separately mapped OSM sidewalk ways or derived from OSM sidewalk tags.

- *‘‘crossing“* marks edges for crossing the road at zebra crossings or unmarked crossings.

- *‘‘square”* marks edges which have been added to the graph to enable realistic crossing of squares. This information is used to adapt the instructions, for example, to output ‘‘cross town square” rather than ‘‘follow town square”, which would be the default if there was no way to distinguish between square edges and road/sidewalk edges.

- *‘‘steps”* marks edges which represent steps. This information is used in instructions to provide details about whether a route goes up or down some steps.

- *‘‘building passage”* marks edges which are passages through buildings. Further information about the building (street name and house number, and potentially, name) should be added to provide additional context for the instructions.

### 3.2 Landmark Extraction and Assignment of Weights

The goal of the landmark extraction step is to create a list of potential landmarks for navigation. These potential landmarks are input for subsequent landmark selection steps. In line with Duckham et al. (2010) and Rousell et al. (2015), our approach uses information about the type or category of a geographic feature to identify potential landmarks. The geographic features available in OSM are imported into the database using ogr2ogr and filtered based on categories which are represented by corresponding tags in the OSM data structure. The complexity of the OSM data structure distinguishes it from other landmark data sources such as point of interest (POI) lists, yellow pages, and building databases, which tend to have a well-defined structure. Due to the flexible tagging policy of the OSM community and differences in the modeled level of detail, similar real-world objects can be modeled in different ways. For example, a university may simply be represented as an area tagged amenity=university, or as a complex multi-polygon consisting of buildings (tagged with building=university), parking lots, and other details available on the campus.

Our landmark extraction covers potential landmarks that are represented as either points or polygons. Figure 1 presents an excerpt of the SQL view definition to extract potential landmarks from the polygon table of the OSM PostGIS database. The selection of point landmarks is performed in a similar fashion. This approach is very flexible and can be expanded to include any number of additional, more specific landmarks, which might be relevant in different environments. Besides filtering for certain categories, this view definition also takes care to exclude features, which are not suitable as landmarks because they are located indoors or underground.

While available literature describes many approaches for assessing landmark category suitability for navigation (Duckham et al. 2010, Fang et al. 2012), only few publications provide an insight into the results of these assessments. One of the available classifications is provided by Zhu & Karimi (2015), who use three categories from ‘‘more likely” to ‘‘less likely to be landmarks” for their classification algorithm. However, the proposed classification is rather coarse and does not cover all landmark categories, which we consider relevant for pedestrian navigation. To generate an initial ranking of landmark categories by their average suitability as landmarks, which can be derived from OSM, expert input was collected from participants of the Walk21 conference. The experts ranked landmark categories on a continuous scale from ‘‘useless” to ‘‘great”, which was converted to a numeric range from 0 to 100 to compute an average weight per category. Figure 2 presents an excerpt of the SQL view definition that assigns the collected weights to poten-

```
SELECT ...
 FROM osm20151021_vienna.multipolygons
 WHERE (
 multipolygons.amenity IN (
 'restaurant',   'cafe',   'pub',   'bar' ,  'hospital',   'pharmacy',   'place_of_worship',
   'bank',   'theatre',   'cinema',   'bicycle_rental',   'fuel',   'toilets',   'police',
 'prison',   'fire_station',   'library',   'post_box',   'post_office',   'bus_station',   'embassy',
 'telephone',   'fountain')
 OR (multipolygons.amenity IN ( 'school', 'university') AND multipolygons.building = 'yes')
 OR multipolygons.shop IN (
 'supermarket',   'bakery',   'chemist',   'clothes',   'jewelry',   'kiosk',   'hairdresser')
 OR multipolygons.building IN (
 'church',   'mosque',   'synagogue',   'cathedral',   'school',   'university')
 OR multipolygons.tourism IN (
 'museum',   'attraction',   'hotel')
 OR multipolygons.historic IN (
 'memorial',   'archaelogical_site')
 OR multipolygons.leisure IN (
 'park',   'playground')
 OR multipolygons.other_tags -> 'railway' = 'subway_entrance'
 OR multipolygons.other_tags -> 'public_transport' IN (
 'platform',   'stop_position')
 OR multipolygons.other_tags -> 'highway' IN (
 'bus_stop',   'traffic_signals'))
 AND  (place IS NULL OR place NOT IN ( 'neighbourhood') )
 AND NOT (multipolygons.other_tags IS NOT NULL
         AND ((exist(multipolygons.other_tags, 'layer')
             AND multipolygons.other_tags -> 'layer' IN ('-1', '-2', '-3'))
         OR (exist(multipolygons.other_tags, 'indoor')
             AND multipolygons.other_tags -> 'indoor' = 'yes')))
```

Figure 1: Extraction of polygon landmarks from the OSM database

tial polygon landmark features. In combination with the query presented in Figure 1, this provides a weighted list of potential landmark features, which can be used as input for subsequent landmark selection algorithms. Using this approach, it is easy to modify the weights of different landmark categories and fine-tune them to match further user or expert feedback and experimental results.

With both the pedestrian routing graph and the weighted list of potential landmarks in place, it is possible to start generating landmark-based navigation instructions for given pedestrian routes. Pedestrian routes were calculated using the shortest path routing provided by the QGIS network analysis library, but more sophisticated approaches for computing, for example, pedestrian-friendly or particularly scenic routes could be substituted as well.

# 4 Generating Landmark-based Pedestrian Navigation Instructions

This section introduces the algorithm for generating landmark navigation instructions for pedestrian routes given as a list of contiguous edges of the routing graph. The algorithm can be broken down into the following main steps, which are described in detail in the subsequent sections: (1) splitting the full route into episodes between decision points; (2) computing turning instructions; (3) selecting landmarks; (4) computing landmark prepositions; and (5) generating the final route description.

```sql
SELECT
   multipolygons.osm_id,
   multipolygons.name,
   ...
   CASE
       WHEN multipolygons.amenity IN ('place_of_worship')
         OR multipolygons.building IN ('church', 'mosque', 'synagogue', 'cathedral') THEN 94
       WHEN multipolygons.historic IN ('memorial', 'attraction') THEN 91
       WHEN multipolygons.amenity IN ('fountain') THEN 91
       WHEN multipolygons.amenity IN ('police', 'fire_station') THEN 90
       WHEN multipolygons.amenity = 'cinema' THEN 86
       WHEN multipolygons.amenity = 'theatre' THEN 85
       WHEN multipolygons.tourism = 'hotel' THEN 84
       WHEN multipolygons.amenity IN ('restaurant','cafe','pub','bar') THEN 84
       WHEN multipolygons.amenity = 'post_office' THEN 83
       WHEN multipolygons.other_tags -> 'railway' = 'subway_entrance' THEN 83
       WHEN multipolygons.shop = 'supermarket' THEN 81
       WHEN multipolygons.amenity = 'pharmacy' THEN 79
       WHEN multipolygons.tourism = 'museum' THEN 79
       WHEN (multipolygons.amenity IN ('school', 'university') AND multipolygons.building = 'yes')
         OR multipolygons.building IN ('school', 'university') THEN 75
       WHEN multipolygons.leisure IN ('park','playground') THEN 75
       WHEN multipolygons.amenity = 'hospital' THEN 75
       WHEN multipolygons.amenity = 'fuel' THEN 75
       WHEN multipolygons.amenity = 'library' THEN 71
       WHEN multipolygons.shop IN ('bakery', 'chemist', 'clothes', 'jewelry', 'kiosk') THEN 50
       WHEN multipolygons.amenity = 'embassy' THEN 45
       WHEN multipolygons.shop = 'hairdresser' THEN 42
       WHEN multipolygons.amenity = 'bank' THEN 38
       WHEN multipolygons.other_tags -> 'public_transport' IN ('platform','stop_position')
         OR multipolygons.other_tags -> 'amenity' IN ('bicycle_rental', 'bus_station') THEN 30
       WHEN multipolygons.amenity IN ('post_box','toilets', 'telephone') THEN 20
       ELSE 50
  END AS nav_priority
  FROM osm20151021_vienna.multipolygons
```

Figure 2: Assignment of weights based on landmark categories in the OSM database

## 4.1 Splitting the Route into Episodes

This first step analyzes the route and segments it into episodes between decision points. A decision point is characterized by at least one of the following: a change in the route direction, a change of the street name, or a change in the type of way. To detect these changes, we perform a pairwise comparison of successive edges of the route. The check for changes in route direction needs to account for a certain tolerance to allow minor direction changes, which would not be characterized as turns. (The issue of turns is discussed in more detail in Section 4.2.)

While this approach often provides a reasonable segmentation into route episodes, the results are highly dependent on modeling details of the routing graph, in particular when it comes to detecting relevant direction changes. Figure 3 illustrates this issue using the example of Fichtegasse in Vienna, Austria: A pedestrian following Fichtegasse only needs to cross Hegelgasse and continue straight on. From the pedestrians perspective, there is no need for a decision point and associated navigation instructions. From the algorithm's point of view, this simple route section contains two potential decision points due to the layout of the routing graph at this intersection, which results in a zig-zag route and thus introduces two direction changes (‘‘slightly left” followed by ‘‘slightly right”) within six meters.

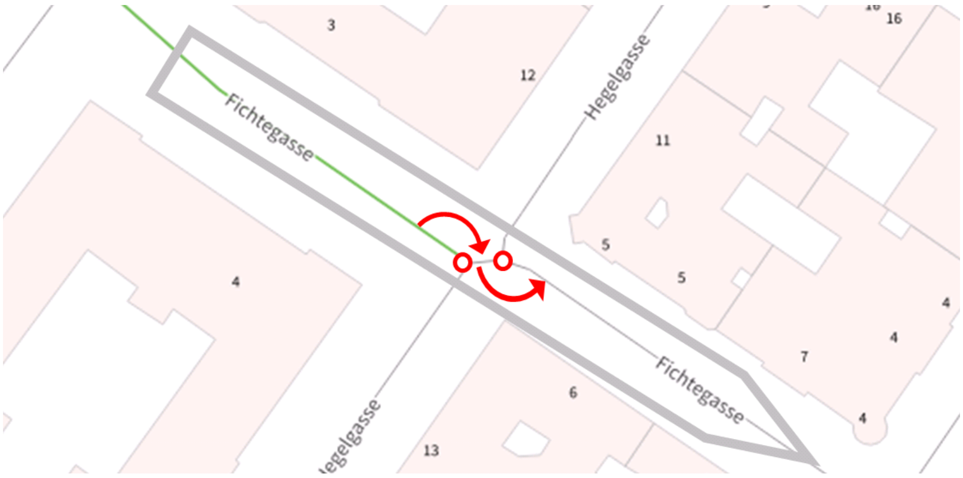


Figure 3: Detecting relevant direction changes in zig-zag routes

Since the issue of zig-zags is frequent in pedestrian routing graphs, which contain sidewalk edges, pedestrian crossings, and other short features, we recommend a preprocessing step, which merges short zig-zag sections, that are below the length limit and not essential to the route description like pedestrian crossings or steps, as follows:

Figure 4 illustrates the algorithm with three examples. Example (a) is similar to the situation in Fichtegasse, no significant route direction change remains after the preprocessing. In example (b), one significant route direction change remains instead of three changes in the original route. In example (c), the short pedestrian

**while** *the route contains an edge e shorter than the length limit, which is not of type pedestrian crossing or steps* **do**

  Replace e by a node at its center point c;
  Connect c to the second to last node of the previous edge and the second node of the following edge;

**end**

**Algorithm 1:** Algorithm to merge short zig-zag sections

crossing edge is not removed in order to preserve the information for the route description computation in a later step. This reduction of decision points caused by zig-zags in the route geometries avoids unnecessary navigation instructions, which are potentially confusing for pedestrians.

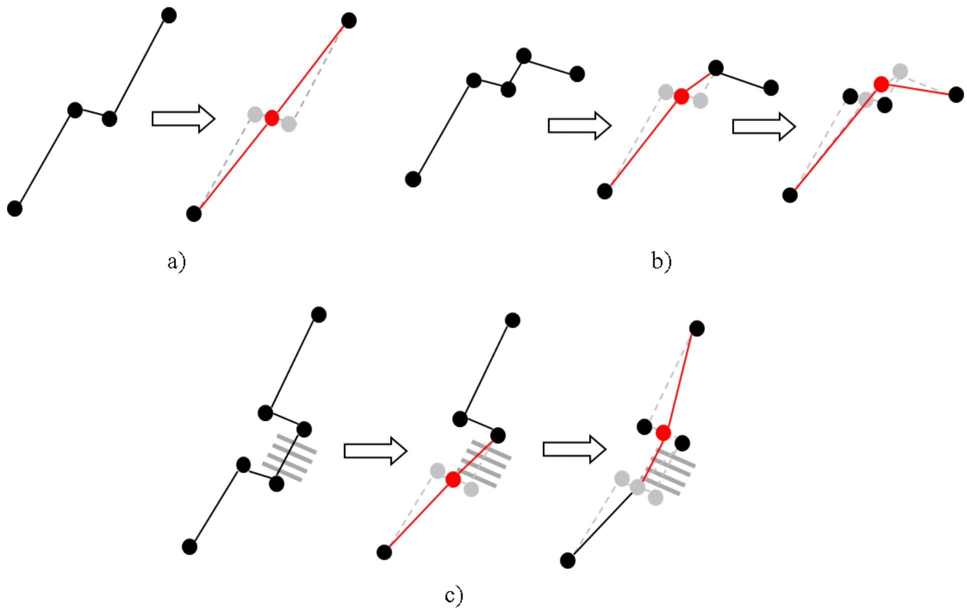


Figure 4: Examples illustrating the algorithm for merging zig-zag sections

## 4.2 Turning Instructions on Pedestrian Routing Graphs

This step covers the computation of turning instructions at the decision points between episodes. The use of turning instructions in human spatial cognition and particularly wayfinding has been studied, for example by Levinson (1996), Montello et al. (1999) and Waller et al. (2004). To compute turning instructions automatically, it is necessary to evaluate the route geometry and derive a fitting turn description.

Klippel & Montello (2007) discuss the conceptualization of turn directions along routes using experiments where participants had to label turns. The seven distinguishable directions they use are half left, left, sharp left, straight, half right, right, and sharp right. The turn angles associated with these labels are also discussed, but its not clear from literature that any certain configuration would provide consistently better navigation performance results than others. For example, Klippel & Montello (2007) argue that in case of decision points and associated changes in travel direction, the labels left and right describe sectors centered on the orthogonal axes of 90 and 270. We adopt this approach and also add a sector for the straight label, as illustrated by Figure 5, to allow for some deviation ($\alpha$) from the completely straight line. Implementation-wise, the mapping of turn angles to associated labels is a configuration setting that can be adjusted easily to evaluate different combinations.

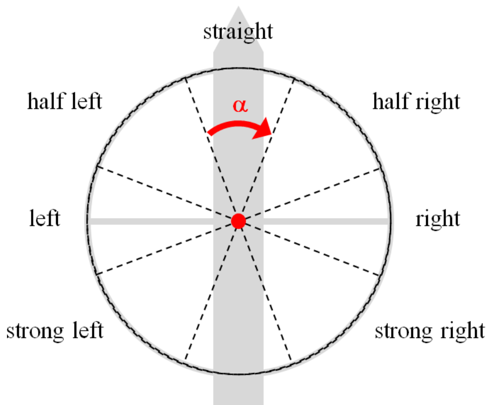


Figure 5: Turn angles at the decision point and associated labels

## 4.3 Landmark Selection at Decision Points

The aim of the landmark selection is to pick the most suitable landmark at a given decision point. Particularly in busy urban settings, there can be numerous potential landmarks in close vicinity of a decision point. Therefore it is necessary to find the most suitable landmark for navigation purposes. Approaches to determine this suitability, from databases, which contain information about the object type but lack details needed to determine the object's salience, are described, for example, by Duckham et al. (2010) and Rousell et al. (2015). In Duckham et al. (2010), the suitability of a landmark candidate is determined using weights based on the expected properties of its landmarks category (e.g. hotel, restaurant ...). They also suggest to prefer landmark candidates which are easily visible from the direction of travel and are located on the side of the street that the next turn will be made toward. Similarly, in Rousell et al. (2015), the suitability of a landmark candidate is determined based on: ‘‘how far the candidate is from the turning point, whether the traveler will pass it or see it in the distance, and whether they will be able to see it on their approach to the waypoint” but they do not use category weights.

We suggest the following algorithm to determine landmark suitability from the database of weighted potential landmarks (described in 3.1.3), which combines and expands previously published approaches into one landmark suitability measure:

$$S = (d_{max} - d) * w_d - (c_{max} - c * \frac{d_{max}}{c_{max}} * w_c + s * w_s + l * w_l + v * w_v, \quad (1)$$

where
$d$ is the distance between decision point and landmark,
$d_{max}$ is the maximum distance for a candidate to be considered,
$c$ is the landmark category weight,
$c_{max}$ is the maximum landmark category weight (100 in our application),
$s$ is the side of the landmark relative to the next turn: same side (1) or other side (0),
$l$ is the location of the landmark relative to the route: before (1) or after (0) the decision point,
$v$ is the visibility of the landmark (see below on how to estimate this value): visible (1) or hidden (0),
and $w_d$,$w_c$,$w_s$,$w_l$,$w_v$ are the weights for the terms for distance, category suitability, side, location, and visibility.

Distances between landmarks and decision points are computed as follows: for point landmarks it equals the Euclidean distance between point and decision point; for polygon landmarks it equals the distance between decision point and polygon outline.

Landmark visibility estimates can be computed using different approaches. Two methods are outlined here. The visibility method introduced by Rousell et al. (2015) estimates a landmarks visibility on the approach to the decision point using line of sight computations, which take building information into account to determine occlusions. Point landmarks (which are often located inside buildings) are buffered to create buffer polygons, which extend outside the containing building polygon. This step is one of the challenges of this approach. It is necessary to determine a suitable buffer size and it assumes that the location of landmark points inside buildings is reliable. Furthermore, the computation of lines of sight makes this approach computationally expensive. To avoid expensive calculations on questionable point landmark locations, our visibility method estimates visibility using distance. Any landmark that is within a certain distance (which can be hard-coded or dependent on the distance between the decision point and the nearest building) is assumed to be visible. The downside of this approach is that it ignores potentially available information about visibility and occlusion by buildings.

## 4.4 Computation of Prepositions

The aim of this step is to determine the relative position of the landmark with respect to the decision point. We distinguish between three different prepositions: *‘‘before”* if the landmark is in front of the decision point, *‘‘at”* if the landmark is at approximately the same location along the route as the decision point, and *''after''* if the landmark lies behind the decision point

Similar to the turning instructions, prepositions are determined based on the angle between the movement direction and the location of the landmark, as illustrated by Figure 6. In the case of polygon landmarks, the angle is computed using the polygon centroid rather than its outline since the different points on the outline can fall into different preposition sectors and would thus lead to ambiguous results as depicted in the example for polygon landmark LM3 in Figure 6.

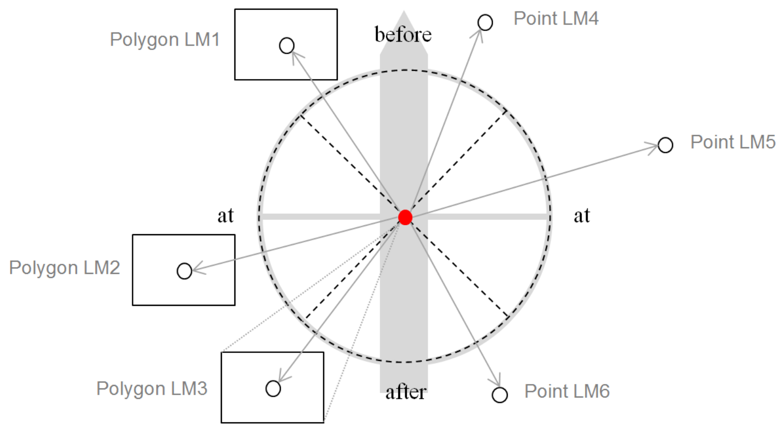


Figure 6: Landmark locations relative to the decision point and associated preposition sectors

One particular challenge for generating intuitive navigation instructions worth noting are big polygon landmarks, since they might be selected for multiple successive decision points. This can lead to confusing and ambiguous navigation instructions. If the same landmark-preposition combination is selected for multiple decision points, it is therefore recommended to repeat the landmark selection and preposition computation steps and exclude the problematic landmark.

## 4.5 Generating the final route description

To generate the final route description, we combine the results of the previous steps and information associated with the episode edges. The route description contains turn instructions, landmark information (landmark with preposition), and information about the traveled edges. The instructions distinguish between different edges, such as, sidewalks, crossing of streets or open spaces (such as squares and plazas), building passages, and steps. The following example presents the elements describing the route depicted in Figure 7, which crosses the street and then turns right at the intersection.

Listing 1: Final description for the route depicted in Figure 7

```
Edge: sidewalk along <street name 1>
  Turn instruction: right
```

```
  Landmark:          Polygon LM1
  Preposition:       at
Edge: pedestrian crossing of <street name 1>
  Turn instruction: left
  Landmark:          Point LM2
  Preposition:       before
Edge: sidewalk along <street name 1>
  Turn instruction: right
  Landmark:          Point LM2
  Preposition:       after
Edge: sidewalk along <street name 2>
```

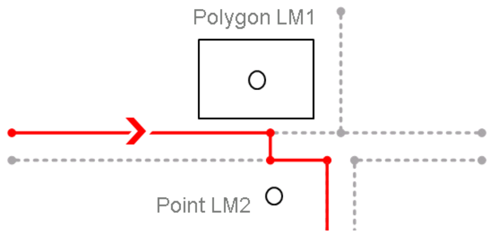


Figure 7: Example of a possible route within the pedestrian graph

These route descriptions can be provided via an API and presented to pedestrians using, for example, apps on smart phones or watches. Implementation details to consider include the combination of textual and map-based route descriptions as well as potential other channels, such as audio descriptions.

# 5 Discussion and Conclusion

To test the results of our algorithms, the landmark-based navigation instructions have been tested with pedestrians in a real-life urban setting. Navigation instructions for two 10 minute long routes with 9 and 17 instructions, respectively, were printed on paper and handed out to the participants. In total, 12 participants (6 male and 6 female, average age 28.5) took part in this test. Results showed that our landmark selection algorithm with weighed landmarks clearly outperformed the baseline approach of selecting the nearest landmarks. Both a reduction in navigation errors, as well as a higher reported quality of landmark-based instructions were observed for the weighed landmark selection. The test also revealed challenges for the generation of intuitive pedestrian navigation instructions: One challenge is that the real-world visibility and salience of an individual landmark are unknown. For example, while a building might be very salient when approached from the front, it can be nondescript if approached from a different side. Algorithms that can derive information about which side of a OSM polygon feature represents the salient building side therefore have the potential to further improve the selection process. Furthermore, its important to reduce the number of instructions and in particular to remove unnecessary instructions in short succession by reducing the number of decision points caused by zig-zags in the route geometries, which cause confusing navigation instructions.

Future work will focus both on algorithmic improvements as well as more user tests. These tests will be performed using an app rather than paper printouts, which will provide us with the opportunity to be more flexible in the test setup and execution. Planned tests include the evaluation of the impact of removing zig-zags in the route geometries in order to reduce the number of navigation instructions. Furthermore, app-aided tests will enable us to vary the weights in the landmark selection algorithm and to use different settings for the computation of turn instructions and prepositions. Algorithmically, we further plan to investigate the use of two more types of landmarks, which have not been included so far: linear features, such as rivers or railways, as well as global landmarks, which can be used to communicate the general direction, in particular at the route starting point.

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