Structural Salience of Landmarks for Route Directions

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Abstract. This paper complements landmark research with an approach to formalize the structural salience of objects along routes. The aim is to automatically integrate salient objects—landmarks—into route directions. To this end, two directions of research are combined: the formalization of salience of objects and the conceptualization of wayfinding actions. We approach structural salience with some taxonomic considerations of point-like objects with respect to their positions along a route and detail the effects of different positions on the conceptualization process. The results are used to extend a formal language of route knowledge, the *wayfinding choreme theory*. This research contributes to a cognitive foundation for next generation navigation support and to the aim of formalizing geosemantics.

1 Introduction

This paper investigates the structural salience of objects along routes. The structural qualities considered are induced by embedding the route into a street network. Objects are called *structurally* salient if their location is cognitively or linguistically easy to conceptualize in route directions.

A generic and formal method of assessing the structural salience of objects with the goal of finding a landmark selection process for route directions is proposed. Such a measure of structural salience complements a formal model of salience recently developed (see, e.g., [1, 2]), building on an earlier characterization of the nature of landmarks [3]. This model assumes visual, semantic and structural qualities of objects that contribute to their salience. Measures for structural qualities have been left out of this model so far, a gap which will be filled by this paper.

The proposed method in this paper utilizes a conceptual approach to spatial information exemplified by route direction elements (e.g., [4, 5]), and extends the wayfinding choreme approach, i.e., a formal language for the specification of conceptual route knowledge, for the inclusion of salient features. This paper classifies structural aspects of landmarks, especially their location with respect to the re-orientation actions performed at the nodes of the underlying street network, which are frequently called decision points.

The linguistic complexity of characterizing the relative location of a landmark is discussed in relation to the conceptual complexity of realizing its wayfinding affordance.

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The hypothesis in this paper is that the conceptual complexity influences the selection of a landmark by direction givers, and hence, the salience of this landmark.

The described approach of the paper brings together two lines of research that have been unrelated so far: the formalization of salience and the conceptualization of wayfinding actions. The paper is organized as follows: We start by reviewing work on landmarks and conceptualization processes relevant for interactions with spatial environments. For the conceptualization of landmarks as route elements we start by instantiating a taxonomy that classifies the location of landmarks with respect to routes. Building on this general classification scheme, we detail the different possibilities of locating landmarks at decision points. We investigate the conceptual complexity of using different types of landmarks, and derive a measure of structural salience from their ease of use. This measure can be combined with the existing measures for visual and semantic salience [1]. We briefly discuss the extension of the wayfinding choreme theory and the formalization of conceptual route knowledge by relying on the developed taxonomy, and conclude with a discussion.

2 Landmark research and conceptual approaches to spatial information

Since the work by Lynch [6] on elements that structure our urban environmental knowledge, the concept of landmarks has inspired multiple research papers. There are some simple and straightforward facts that can be manifested from this research:

- Everything that stands out from a scene can be a landmark [7].
- In certain contexts, for example route following, even road intersections can be landmarks.
- Landmarks are pertinent for finding one's way.
- Landmarks are remembered/learned early on (i.e., landmark knowledge) [8].
- Landmarks structure environmental knowledge, for example, as anchor points [9].
- Landmarks are used to communicate route knowledge verbally and graphically [10].
- Landmarks are integrated in route directions to varying degrees, with greater quantities at origins, destinations and distinguished decision points [11, 12].
- Landmarks at street intersections (decision points) are more pertinent when a change in direction is required [13].
- Landmarks generally work better than street signs in wayfinding (e.g., [14]).

While we understand how and why, *people* use landmarks in communication, and hence in memory and mental processes, the technical basis to *automatically construct* wayfinding directions with landmarks is still limited. Suitable formalisms for characterizing conceptual route knowledge that can be flexibly adapted to canonical and personal preferences are still missing.

Part of the problem is formalizing the concept of a landmark, such that a service can identify objects of some *landmarkness* or salience, i.e., objects that differ from their background [7]. According to a recent proposal [1, 2, 15] the salience of objects is determined by visual, semantic and structural qualities. These qualities can be characterized to provide an overall measure of salience. The approach proposes measures for visual qualities (such as the size, form, or texture of an object), and semantic qualities (such as their prominent or labelled use); measures for structural qualities have not been included so far. Objects that show large visual and semantic salience show good compliance with cognitively salient objects, i.e., landmarks chosen by people for their communication of routes.

The measure of salience can be adapted to context [15], and can be weighted by advance visibility along a route [16], which makes it route specific. The approach has also been adopted for data mining in topographic data sets [17, 18].

An approach orthogonal to the work on the salience of objects is taken by wayfinding choreme theory [19, 4, 20]. This approach, however, can provide the missing aspect of structural salience. It is based on wayfinding events such as re-orientations and turns at street intersections as primitives; conceptual primitives of turns are derived from this.

The conceptualization of actions and events[3] and their formal specification is a recently well discussed area of research [21, 22]. Complementary to other computational formalisms [23] the wayfinding choreme theory stresses the cognitive aspects of route knowledge by making (cognitive) conceptual primitives the basis of the formalism. Yet, the focus on conceptualization and the development of a formal language [4] offers many ties to recent discussions on the formalization of conceptual spaces [24], e.g., for landmarks [25], and the general approach of integrating cognitive semantics (sometimes referred to as conceptual semantics) into information systems [26]. The wayfinding choreme approach seeks conceptual primitives as a foundation for a formal language of space in which the number of basic elements are restricted and the combinatorial possibilities are constraint by the represented knowledge, in our case, the linear character of a route. Additionally, the focus on conceptual aspects of information creates a basis for multimodality in that the externalization of conceptualizations can be specified in various output formats (e.g., [12, 27]): verbal, graphical or gesture.

The conceptualization of an action at a decision point, however, is not only dependent on the angle of the turn, i.e., the geometric representation of the trajectory of the movement, but also on the street structure in which the action is embedded [28]. Additionally, the possibility of relating the turning action to supplementary information—for example a landmark—has an influence on the conceptualization.

A formal specification of conceptual primitives of landmark locations should therefore allow the characterization of different layers of interaction with the environment and grasp the resulting conceptual primitive adequately. In this paper, we will further elaborate the conceptual approach and focus on landmarks, specifically their structural salience induced by the conceptualization of a wayfinding action. Based on this characterization we will extend the rules specified for the higher order route direction elements (HORDE) [29, 30] to allow for different levels of granularity in route directions.

[3] In this article we do not distinguish between actions and events.

3 Conceptualizing landmarks as route elements

Some of the observed characteristics of landmarks discussed in Section 2 concern their structural qualities with respect to a given route: the route structure (co-)determines which salient objects are selected to give route directions. Hence, this paper develops a classification schema for point-like landmarks depending on their location relative to a route and the route's structural embedding in the street network. For some ideas on other types of landmarks and their relation to route directions see [20]. We further show that some locations are conceptually easier and conceptually less ambiguous than others, especially with regard to building complex route elements, i.e., combining conceptual primitives into HORDE.

3.1 Landmark locations

The following taxonomy of landmarks induced by a route embedded into a street network is illustrated in Figure 1. Landmarks can occur (i) distant from the route (distant landmarks), (ii) somewhere along route segments (segment landmarks), or (iii) at specific route nodes (node landmarks). Segment landmarks and node landmarks can be grouped as either close to or on-route. Route nodes are also called *decision points*.

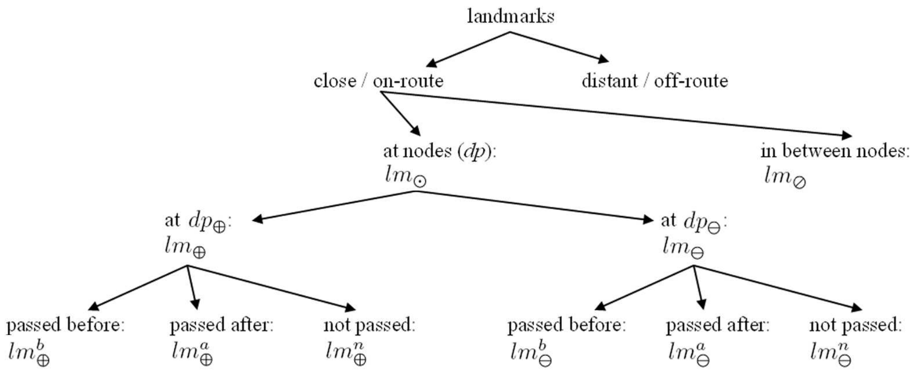

Fig. 1. A structural taxonomy of landmarks; the abbreviations are detailed in the text.

Distant and on-route landmarks. With respect to a route, these categories of landmarks have different degrees of freedom regarding their location. A distant landmark is not determined in its exact location in two dimensions. The conceptualization details an area, a region in which the landmark is placed, or a line of sight. A segment landmark, on the other hand, has its location determined only within the one-dimensional interval between two route nodes; their exact location along the segment—the linear reference from start or end node—remains under-specified. In contrast, node landmarks are constrained in their location by a node of the street network or decision point. With respect to their function in route directions and the conceptualization of the action that has to be performed, both their location and their remaining degrees of freedom in location have to be reflected, for example, in the type of verbal reference.

Distant landmarks fulfill a variety of functions, for example, global orientation, reassurance and confirmation [31]. Their actual location (or distance) is irrelevant as long as the direction or visibility can be taken as reference. Distance generally is not a criterion for exclusion from route directions. Consider for example the route direction:

Follow the street until you see the castle distantly on your right. (1)

Yet, the effect of distant landmarks on the conceptualization of route parts, for example, spatial chunking [32], is rather complex. Many parameters that influence the conceptualization of these distant landmarks are not primarily spatial (at least not planar spatial). They are therefore not the focus of this paper.

Within the category of landmarks that are close to or on-route (cf. [33]) segment landmarks [34] are used for reassurance and confirmation. The influence of segment landmarks on chunking is discussed in Section 3.3. In contrast, node landmarks may be used as an anchor for action (re-orientation and turning), and hence, their location with respect to the route is relevant. But node landmarks can also occur at decision points where no re-orientation is necessary. Within our taxonomy we write segment landmarks as $lm_{\oslash}$, and node landmarks as $lm_{\odot}$.

Route directions cannot neglect any necessary re-orientation, but they can neglect confirmations that may occur either between decision points or at decision points where no re-orientation is required. That means, node landmarks at decision points with re-orientation are essential, and other landmarks are less important or optional. This characterization establishes a first indication of structural salience.

Node landmarks. A further common distinction is made between decision points with direction change, $dp_{\oplus}$, and decision points without direction change, $dp_{\ominus}$. This distinction has to be accounted for in the taxonomy of node landmarks. It has been shown that landmarks at $dp_{\oplus}$ are more pertinent to route knowledge [11, 13]. Within our taxonomy we coin them $lm_{\oplus}$, and landmarks at $dp_{\ominus}$ are coined $lm_{\ominus}$, such that $lm_{\odot} = \{lm_{\oplus}, lm_{\ominus}\}$.

At a more detailed level of spatial granularity, it is of interest *where* with relation to any decision point, $dp_{\oplus}$ or $dp_{\ominus}$, a landmark is placed. Not every node landmark is equally suited to aid wayfinding and to be integrated into route directions and the conceptualization of route parts, respectively.

Note that this characterization is based on locational properties, i.e., the location of a landmark with respect to the physical layout of an intersection. It is not a characterization based on the visual or semantic salience of a landmark. This characterization is also a specification of the locational properties from the perspective of mental conceptualization processes, i.e., the conceptualization of an action performed in a spatial environment. In experimental settings (e.g., in [32]) it was made sure that at $dp_{\oplus}$ primarily those landmarks that can be integrated into a route direction conceptually easily are used. This integration is afforded by the landmarks' location with respect to the action at the decision point. More specifically, landmarks at $dp_{\oplus}$ were chosen that are passed immediately before a turning decision. These node landmarks may be located on the left or on the right side of the route, independent from the direction of the turn. A natural language example would be:

$$\text{Turn right after the post office.} \tag{2}$$

Based on the idea that the action performed (or imagined) at a decision point is the pertinent factor for the conceptualization process, we introduce further sub-concepts for landmarks, namely landmarks passed before the action is performed, lm^b, landmarks not directly passed, lm^n, and landmarks passed after decision, lm^a (see Figure 1, and also Figure 2 for more details). These concepts can be specified for decision points with a direction change, but also for decision points without a direction change.

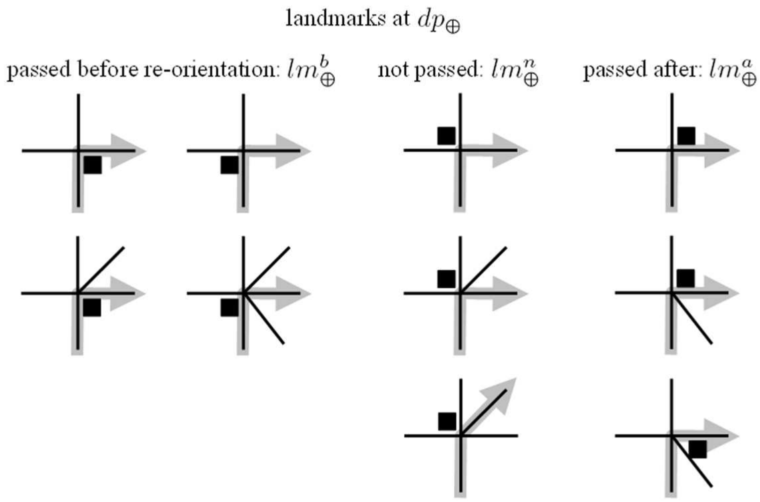

Fig. 2. Possible locations of node landmarks with re-orientation. The different locations result in different conceptualizations, and not every location of a landmark functions equally well as an identifier for the required decision.

At $dp_{\oplus}$, landmarks passed before decision, $lm^b_{\oplus}$, work equally well for all turning concepts. That is, they are straightforward to conceptualize as the turning occurs immediately after them and does not conflict with the overall branching structure of the decision point. Compare the use of a $lm^b_{\oplus}$:

$$\text{Make a sharp right turn after the post office.} \tag{3}$$

with a $lm^n_{\oplus}$ or $lm^a_{\oplus}$:

$$\text{Make a sharp right turn at the intersection where the post office is.} \tag{4}$$

which represents here a more precise, but also more complicated direction *'make a sharp right turn at the intersection where the post office is at the opposite corner'*. Especially at more complex intersections, where it is difficult to conceptualize the location of a landmark, a $lm^b_\oplus$ is the only unambiguously identifiable one.

3.2 A route direction grammar with node landmarks

Having a taxonomy for the location of landmarks with respect to a route, we can integrate them into the wayfinding choreme route grammar [4]. Generally, two turning concepts have been differentiated, standard turning concepts $\langle \texttt{STC} \rangle$ and modified turning concepts $\langle \texttt{MTC} \rangle$ [4]. Both can be extended to incorporate the different landmark locations. To this end, the node landmark and its location is added to the wayfinding choreme grammar as an annotation. We exemplarily detail the notation for the wayfinding choreme of a right turn, $\texttt{wc}_r$, added with a landmark passed before the decision, $lm^b_\oplus$:

$$\langle \texttt{wc}_r^{lm^b_\oplus} \rangle \tag{5}$$

Likewise for other turning concepts.

3.3 Spatial chunking with node landmarks

This section exemplifies the influence of structural aspects of landmark positions within yet another aspect of route directions, the change in granularity by applying higher order route direction elements (HORDE). We discuss here the possibilities of chunking with node landmarks at decision points without a direction change, $lm_\ominus$preceding a $dp_\oplus$. $lm_\ominus$ have two functions: First, they are used to identify a decision point resulting in a verbalization such as *'go straight at the intersection where the McDonald's is'*. Second, they are used in a way analogous to a segment landmark $lm_\oslash$, such as *'pass the McDonald's and turn right at the Shell gas station'*. Here it is not specified whether the $lm_\ominus$ is placed at a decision point or between two decision points. The second case might be an example of spatial chunking.

Two distinctions are pertinent for $lm_\ominus$ that determine their function in spatial chunking. First, whether the landmark is passed before ($lm^b_\ominus$) or after ($lm^a_\ominus$) the action of straight crossing the intersection. Second, whether a landmark is present at the chunk terminating $dp_\oplus$ ahead. We observe that $lm_\ominus$ only appear within small chunks (similar to segment landmarks $lm_\oslash$) if at least one and possibly both of the following conditions are met: (i) the $lm_\ominus$ is of the type $lm^a_\ominus$; (ii) there is an easy to conceptualize node landmark at the chunk terminating $dp_\oplus$. Figure 3 illustrates these assumptions. The following cases demonstrate some rules that can be distinguished and integrated into the wayfinding choreme route grammar:

- Consider the first example in Figure 3. $lm_\ominus$ is passed before orientation: $lm^b_\ominus$, and at the chunk terminating $dp_\oplus$ there is a landmark. The resulting concept is: PASS 'FIRST LANDMARK' AND TURN RIGHT AT 'SECOND LANDMARK'. This concept is over-specified when only two decision points are present; the first landmark should be left out, even if it is the somewhat more salient one.

– Consider the second example in Figure 3. $lm_{\ominus}$ is passed before re-orientation: $lm^b_{\ominus}$, but no landmark is present at the chunk terminating $dp_{\oplus}$. This situation has to be put in a less specific form: AFTER THE INTERSECTION WHERE THE 'LANDMARK' IS TURN RIGHT AT THE NEXT INTERSECTION, or alternatively, in a more complex concept: AFTER THE INTERSECTION WHERE THE 'LANDMARK' IS AT THE RIGHT CORNER TURN RIGHT AT THE NEXT INTERSECTION.
– Now turn to the third example in Figure 3. $lm_{\ominus}$ is passed after re-orientation: $lm^a_{\ominus}$, and a landmark is present at the corresponding $dp_{\oplus}$, for example, a $lm^b_{\oplus}$. The resulting concept is similar to the first case: PASS 'FIRST LANDMARK' AND TURN RIGHT AT 'SECOND LANDMARK'. When only two decision points are involved, the first landmark is left out.
– Finally, consider the fourth example in Figure 3. $lm_{\ominus}$ is passed after re-orientation: $lm^a_{\ominus}$, but no landmark is present at the corresponding $dp_{\oplus}$. Here, $lm_{\ominus}$ is used similarly to a $lm_{\oslash}$: TAKE A RIGHT TURN AFTER 'LANDMARK'.

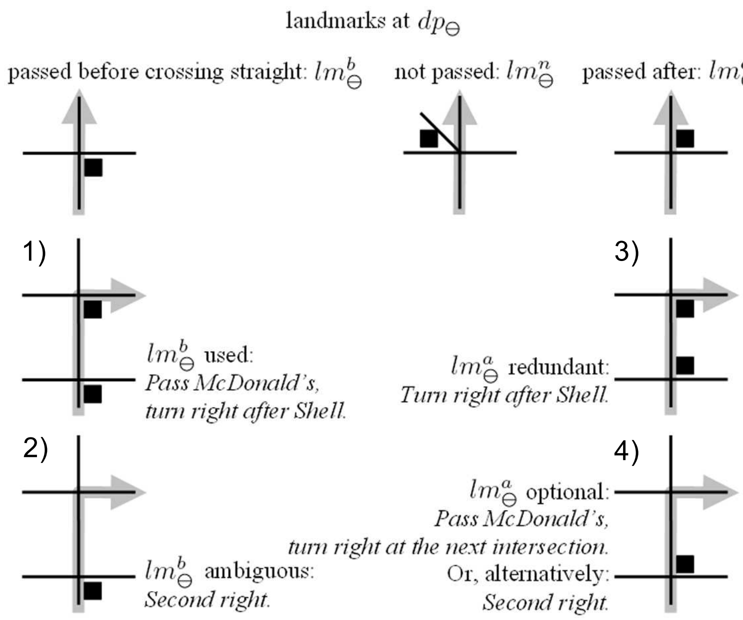

Fig. 3. Landmarks at a decision point without a direction change, and their influence on spatial chunking in examples 1-4.

So far, distance has not been considered. There are, however, similarities to another approach to integrate distance in term rewriting as a method to extract conceptually connected primitives [35]. A more detailed characterization of spatial situations to differentiate, for example, the following two concepts is ongoing research: (a) MAKE A RIGHT AND THEN ANOTHER QUICK RIGHT, versus (b) MAKE A U-TURN.

4 Structural salience of landmarks

The previous sections discussed the conceptual approach to characterize the positions of landmarks with respect to their relevance for route directions. This section extends the salience model for landmarks to include structural aspects derived from the findings above.

4.1 The salience model

The salience model [1, 2] provides a measure of salience for all identified objects within a street network. These measures enable choosing the most salient objects along a specific route, for example, at decision points with direction change, to enrich route directions. For static objects the measures can be calculated once, and stored as parameters of the objects.

The original model of salience was based on three qualities: visual, semantic and structural [3]. Each quality can be characterized by a normed measure of salience (with values $0 \dots 1$), resulting in visual salience s_v, semantic salience s_s, and structural salience s_u. These measures can be combined to a weighted average of joint salience, s_o:

$$s_o = w_v s_v + w_s s_s + w_u s_u \qquad \text{with } w_v + w_s + w_u = 1 \tag{6}$$

So far, structural salience has been considered in the model, but it was not developed. Saliences s_v and s_s are determined by comparing visual and semantic properties of objects with the properties of other objects in their neighborhood. The more distinct a property of an object is, in its neighborhood, the higher the object's salience measure is. By this way, the figure-ground relation mentioned in Section 2 is quantified. This means:

- Visual and semantic salience is dependent on the properties of objects nearby; it is a relative property of an object, not an absolute one. For instance, a red facade in an area where all facades are red will not stand out. But the same facade in a grey neighborhood stands out.
- Joint salience is quantitative, i.e., it can be represented by a real number between 0 and 1. It is not qualitative (e.g., 'landmark', 'no landmark'), as supposed so far in the previous sections.

It was shown further that weighting individual visual and semantic criteria differently allows for adapting the salience measure to different wayfinding contexts [15].

This original model of salience was investigated for one class of objects: facades of buildings. Consider for example Figure 4, which shows eight street facades of buildings at a street intersection, and their visual and semantic salience represented by grey intensity. According to the original salience model we would choose the object of highest salience (in Figure 4, one of the two facades of building *c*) as a landmark for route directions.

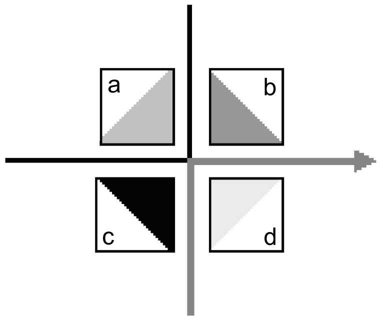

Fig. 4. A street intersection with eight street facades; each individual facade has a salience indicated by grey intensity.

4.2 Advance visibility

Visual and semantic salience characterize properties of objects that are independent from routes and the street network. Route dependent properties of objects can be considered additionally. Each object can be related to an infinite number of routes, but locally the number of combinations, i.e., the number of approaching directions, is small. This means local route-dependent properties can be represented by a small number of fixed parameters. This number is rarely larger than four; extreme cases, such as the Arc d'Triomphe in Paris, extend already the concept of an intersection to a large circle which can be considered as comprising of several intersections.

The salience model can be extended by *advance visibility* [16]. This measure characterizes the visibility of the object from an approaching direction, and hence, is different for each approaching direction. The rationale for this additional component is that the most salient object at a decision point can form a poor reference in a route direction if it is not visible in advance but an alternative salient object is. Thus advance visibility s_a has to be balanced with joint salience to characterize total salience s_t, e.g., by multiplying the two measures:

$$s_t = s_o * s_a \tag{7}$$

Note that s_a is also a normed value between 0 and 1. Multiplication favors objects that are at the same time at least *to some extent* jointly salient and *to some extent* visible in advance, compared to salient but not visible, or visible but not salient objects. This behavior seems to be reasonable.

Consider for example Figure 4 again. The four facades facing towards the street the wayfinder is approaching are all visible to the wayfinder, but from the four facades facing the cross-road two are only partially visible (4(a) and (b)), and two are not at all visible (4(c) and (d)). Hence, the total salience s_t is largest for the facade of the building *c* that faces towards the street the wayfinder approaches. This facade should be used for route directions if we consider visual and semantic salience and advance visibility.

At this stage, we have a model that ranks objects by salience and advance visibility, but remains indifferent to the structural characteristics of the relation between objects and street network, or to the relation between objects and routes. However, in Section 3 we saw that the relationships between landmark, route and street network influence the selection process of landmarks. The integration of the structural properties of objects in the salience model still needs to be done. This means we have to develop

- normed salience measures for the identified structural properties of objects (s_u);
- an adaptation of higher order route direction elements (HORDE) for quantitative measures of landmarkness.

4.3 Structural salience

The discussion of structural properties of landmarks in Section 3 showed that

1. structural properties of objects co-determine their suitability as a landmark;
2. structural properties are, if not quantitative, at least ordered, such that a specific weight of at least an ordered scale can be attached to each situation;
3. structural properties are determined by the structure of the underlying street network, and locally route dependent, which means they are countable and constant.

The set of weights should reflect the hierarchy of Figure 1, and the distinctions of Figures 2 and 3. The order reflected in these figures is motivated by the previous discussions, and partially validated by cognitive, behavioral or linguistic experiments. Presently, we convert the ordered scale measures of structural salience into ratio scale by matching an equally partitioned interval from 0 to 1. However, determining more realistic ratio scale weights needs careful human subject testing and is beyond the scope of this paper.

The third aspect—countable and constant measures—means that the measures can be stored as properties with each object. They are route- and street network dependent, and hence their combinatorial complexity is higher than, for example, for advance visibility. For node landmarks, for example, the complexity is $n(n-1)$, with n being the node degree of the street intersection, because the structure requires consideration of not only the incoming direction, but also the one going off. Note that this includes the distinction between node landmarks with re-orientation, $lm_{\oplus}$, and landmarks without, $lm_{\ominus}$. This means with street intersection degrees of rarely larger than four the complexity is rarely larger than twelve.

The measure of structural salience can be integrated into the original model of salience (Eq. 6). It is still one of three components that add up, i.e., an object is salient if it is visually, semantically *or* structurally distinct.

If we survey people for measures of structural salience with the one-dimensional configurational relationships, the results might be mixed up with expectations of advance visibility. However, in the motivation for structural distinctions we only argued for cognitive and linguistic simplicity. Hence, advance visibility is different and remains a component of total salience (Eq. 7).

For an illustration, consider the situation in Figure 5. The situation shows a route at a decision point with direction change, and some facades with their measures of salience. According to the discussion in Section 3, landmarks at decision points are more pertinent than those along route segments, and at decision points distinctions can again be made in relation to the action (here: turning right). The structural salience measures for the given facades reflect this hierarchy. Note that the structural salience measures recur for buildings (as point-like landmarks), not for facades individually. Advance visibility is assumed to be equal for all facades facing the street the wayfinder approaches to the decision point, less for the facade on the cross-road facing the advancing wayfinder, and zero (not visible in advance) for the facade on the cross-road facing away from the advancing wayfinder.

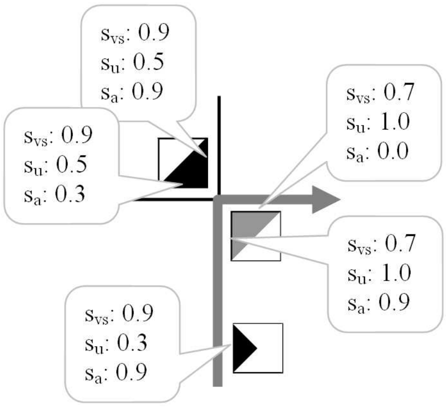

Fig. 5. A route at a decision point with direction change, and measures of salience for some facades (s_{vs}: visual and semantic salience, s_u: structural salience, s_a: advance visibility).

With Equation 7 we derive the (route- and network dependent) measures of total salience for the considered facades shown in Figure 6. In the given spatial configuration, and for the given visual and semantic salience, the facade with $s_t = 0.72$ is the most salient one. This is particularly interesting as it is not the most visually or semantically salient one. Hence taking into consideration the route- and street network dependent aspects can change the priorities significantly, a behavior that was sought for.

4.4 Selection process in HORDE

The original salience model did provide a comparison between objects, but did not look into selection. It still assumed a superordinate selection process that exploits salience measures to select references to salient objects where needed. In contrast, structural salience prioritizes visually and semantically salient objects at specific locations along a route. It establishes a selection process by weighting objects between decision points against objects at decision points and so on.

Compared to the discussion in Section 3.3 the situation at this stage has changed. Objects along the route now have more or less salience, and are no longer categorically considered as 'landmarks'. The measures of salience along a route form a distribution,

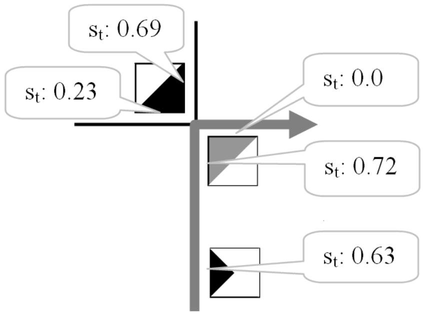

Fig. 6. The total salience s_t for the facades.

which can further support selection. Let us study the distribution of values with two examples:

- Imagine a route through a green suburb of one-family houses. Salience measures of the objects (facades) along the route differ slightly, but no object stands significantly out. The distribution of salience measures has a small variance and no outliers. Selecting the most salient object along a route segment is possible, but not really helpful.
- Imagine a route along Vienna's *Ringstrasse*. There are frequent salient objects (the parliament, the *Burgtheater*, the city hall, the university, the stock exchange, and so on), and the measures of salience vary largely. The wayfinder is attracted, and if the route description only indicates to *'walk straight to the Danube'* and does not mention the attractions, she might feel uncomfortable and wonder if she is on the right track[4].

In other words, in an environment with one or a few outstanding object(s) these objects can be used as 'landmarks' in the categorical sense of Section 3.3. In an environment with no outstanding objects it is better to refer to other (structural) properties, such as the number of intersections. The appropriate method to distinguish these two cases is outlier detection, i.e., basing the decision on the standard deviation of salience in that environment, not on an absolute threshold value.

An object with a large salience has probably, but not necessarily, structural salience as well. This means that objects with large salience measures have a high probability of being at decision points $dp_{\oplus}$, or in another salient structural relationships to the route.

5 Conclusions and outlook

In this paper we have combined two approaches on formalizing route knowledge relevant to the selection of landmarks and for integrating them into route directions: on

[4] An option currently investigated relies on recursion to higher levels of abstraction, such as *'walk straight along the attractive Ringstrasse to the Danube'*.

the one hand the salience of landmarks as dominant objects in route knowledge and route directions, and on the other hand the conceptualization of wayfinding actions in relation to landmarks, i.e., the integration of landmarks in the formal specification of a conceptual route language, the wayfinding choreme theory.

Both approaches on their own are well established and the combination of them results in efficient formalisms addressing several unsolved research questions. Combined, they allow for the specification of structural salience and will complement the basis for an automatic, cognitive adequate generation of route directions in wayfinding assistance systems.

The approach of defining the structural salience of landmarks through the application of a conceptual approach also offers answers to research questions in the area of geosemantics; especially, their formalization, standardization and automatization, for example, for mobile navigation systems. The application of conceptual (cognitive) semantics for geographic information science has recently gained attention through research on ontologies [26].

Other approaches that aim to formally characterize spatial structures have to be considered in greater detail. Especially the approach of space syntax provides several concepts that relate to the topics discussed in this paper [36, 37].

With the precisiation of location of landmarks at intersection the next step in the formalization of conceptual knowledge, especially with respect to different modi of externalization, has been achieved. The dual approach of a generic concept that in general specifies the presence of a landmark and the possibility of a more detailed analysis offers a means to model different levels of granularity in route directions. It also offers a means to contribute the structural salience to models finding salient features by data mining in text documents [38, 39].

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