complexity) of a description offered by verbalizers[1]. All these types of intersections deserve more attention as they offer a suitable means to improve route directions and route information systems, respectively—verbal and graphical ones.

Graphical and Verbal Representations

We generally aim to model route information on a conceptual level (e.g., Habel, 2003; Klippel, 2003; Ligozat, 2000; Richter & Klippel, 2005). That means we do not restrict ourselves predefinitely to a particular modality of representation. Nevertheless, some aspects of information need special treatment due to the representational characteristics of the different media. While in a graphic representation the structure of the special intersections mentioned in the previous section is provided inherently, the verbal description of an intersection needs special treatment to become effective: the pure direction concepts participants use at standard intersections often changes to one of the following (Klippel et al., in prep):

Besides rendering the direction concept precise, for example, by providing detailed descriptions according to a direction model (e.g., *turn very sharp right*), and possibly relying on clock-wise directions (e.g., *turn to 2 o'clock*) or an absolute reference system, participants adopt the following strategies: naming the structure in which the actions take place plus a coarse direction concept (e.g., *fork right*), a comparison of possibilities to take (e.g., *furthest right*), a conceptual change to ordering information plus a coarse direction concept (e.g., *the third to your left*), the description of competing directions not to take, or any combination of these strategies. The situation changes again if landmarks are present.

Despite the differences in other aspects, graphics and language will be treated similarly, for example, in the case of forming so called higher order route direction elements (HORDE). Independent of the representational medium, cognitive processes organize knowledge on different levels of granularities and employ similar principles in doing so (Hobbs, 1985). That means that one of the main aspects of using landmarks, i.e. to organize route knowledge in sensible chunks, is a cognitive strategy that is applicable in both media, language and graphics.

A Little Survey

Given the theoretical and behavioral considerations briefly sketched above we surveyed several internet route planners whether or not they employ spatial structures (a) in general as a special situation and (b) as a landmark to create HORDE. The results are shown in Table 1.

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[1] Note that the complexity of an intersection is not an easy to characterize concept. It depends not only on the configuration as such but also on the action that is or has to be performed at an intersection. This relation between structure and function is explored in Klippel, Tenbrink and Montello (in prep.).

Table 1: Do internet route planners use special intersections to chunk route parts and do they explicitly integrate them in their verbal descriptions?[2]

Spatial Structure	www.de.map24.com		www.mapblast.com		www.maporama.com		www.mapquest.com	
	Concept	HORDE	Concept	HORDE	Concept	HORDE	Concept	HORDE
Roundabout	yes	no	yes	no	yes	no	yes	no
T-Intersection	no	no	no	no	no	no	no	no
Complex Intersection	no	no	no	no	no	no	no	no
Fork	no	no	no	no	no	no	no	no
Tunnel	no	no	no	no	no	no	no	no
Bridge	no	no	no	no	no	no	no	no
Landmark	no	no	no	no	somehow	no	no	no

The survey in table 1 shows that internet route planners predominantly rely on street names and distances (not listed in the table). Hence, the only means that they employ to chunk route parts are street names. Despite the salience of spatial structures and their potential to serve as a landmark only roundabouts are explicitly mentioned in the examined route planners, and often the spatial situation is not further detailed. Most astonishingly, not even the fail safe T-intersections are explicitly mentioned. Users of these systems are faced with underspecified information and have to identify the street to take by reading off the street name while navigating through the street network. The mismatch between graphic representation and verbal description is astonishing (it is often actually a mismatch between the map, a symbol that indicates the turn, and the verbal direction). The only exception is *mapblast* that at least provides a more precise specification of the direction to take.

Improving LBS and Mobile Map Applications

Landmarks are those elements in the environment that help us organize our spatial knowledge and to anchor actions, for example, during route following. Research has shown that landmarks are the preferred means for route communication and route following by human navigators (e.g., Denis, 1997; Lovelace, Hegarty, & Montello, 1999; Tversky & Lee, 1999); and not surprisingly, they are the focus of several technical approaches that aim to improve LBS (e.g., Elias, 2003; Winter, Raubal, & Nothegger, 2004). But intersections as landmarks have been neglected so far. Yet, they offer several advantages: intersections do not require additional information from databases as they can be directly read off the street data. That means they are free of any additional cost and in most cases comparatively reliable in automatic detection in contrast to the approaches that aim to automatically detect landmarks requiring heuristics on rich data sets and often fell short to reliable detect what counts as a landmark. They are also

[2] Note that this survey is based on a few hand selected spatial situations (so far). Nevertheless the authors know of no other exceptions. Any suggestions are most welcome.

comparatively reliable in identification by a human navigator: while the intersections referred to so far are stable, (conceptually) well established configurations that rarely change their structure, objects along the route used as landmarks may be problematic in identification for several reasons, for example, shops may vanish, trees may block the sight, or (simply) it may be dark.

Given a graph-like representation format, the different types of intersections are identifiable by setting geometric constraints. The integration of these constraints has partially been realized in the model for context-specific route directions (Richter & Klippel, 2005), which, for example, identifies and explicitly refers to T-intersections in route directions.

In the following, we exemplify the two initially discussed advantages that can be drawn from our approach, i.e. the specification of the relation between structure and function on the conceptualization of an action at an intersection to increase the clarity of a route direction and the creation of meaningful route parts (HORDE) on the basis of intersection-landmarks. We use the grammatical notation detailed for conceptual route knowledge (Klippel, Tappe, Kulik, & Lee, forthcoming 2005), i.e. the wayfinding choreme route grammar and term rewriting.

The types of intersections identified are added as annotations to the wayfinding choreme notation. For example at T-intersections and forks:

(1) wc_{r}^{T} denote a RIGHT turn at a T-intersection.

(2) wc_{hl}^{F} denotes a HALF LEFT turn at a fork in the road.

Only certain direction concepts are associated with a special intersection. T-intersections, for example, work with basic concepts for LEFT and RIGHT. Forks, on the other hand, work with the concepts HALF RIGHT and HALF LEFT. This specification occurs on the conceptual level; therefore, we only subsequently add the corresponding externalization; the most suitable one with respect to comprehensibility is determined by experimental studies. For example:

(3) wc_{hl}^{F} possible externalizations: *fork left*, *turn diagonally left*, *veer left*.

While this is the basic notation we add to the wayfinding choreme route grammar, we also have to add rules for processing of the route string, which is the result of specifying a route in wayfinding choreme notation. These rules handle the identification of HORDE within the route string. If we want to use, for example, a T-intersection to obtain a HORDE (that could correspond to a verbalization like *turn right where the road dead ends*), we specify this fact as a rule. In this example wc_S denotes a concept for STRAIGHT, stc^T is a standard turn (LEFT and RIGHT) at a T-intersection and dwc^T is the resulting HORDE[3]:

[3] Further details on the notation and the set of basic rules can be found in (Klippel et al., forthcoming 2005)

(4) $$\underbrace{\left(wc_s wc_s \cdots wc_s\right)}_{n-\text{times}} stc^T \rightarrow dwc^T \qquad n \in \mathbb{N},\quad stc^T \in \{wc_r^T, wc_l^T\}$$

In the case of a T-intersection it does not matter how many intersections at which we go straight are passed (Klippel et al., forthcoming 2005). It works likewise with the other types of intersections. A special case are roundabouts as they occur more and more frequent in street networks. Here HORDE initiated by roundabouts could be chunked numerically on the next level (Klippel et al., 2003), resulting in concepts like *turn right (take the first exit) at the second roundabout*.

Outlook

Given the knowledge that landmarks are the most cognitively adequate means to communicate route knowledge it astonishes that only recently the information systems community is focusing on them. Additionally, there has been a predominant research effort on identifying point-like landmarks and the definition of characteristics that makes them salient with respect to their environment. More recently, the structural salience of point-like landmarks has been acknowledged (Klippel & Winter, to appear) and has been integrated in the general salience model (Raubal & Winter, 2002).

Our proposal extends landmarkedness to structural aspects of an environment; so far we concentrate on types of intersections that stand out before the background of a route. Roundabouts, for example, are increasingly popular in planning and building street networks; they are already part of internet based route planners and may become a main feature in structuring route directions.

As future work, more user data is required to determine the geometric constraints for the intersection types, for example, to specify in which case an intersection is regarded as a fork. This general conceptualization has to match a human navigator's perception. The behavioral basis and the formalization of direction concepts in street networks is an ongoing line of research (e.g., Klippel et al., 2004; Klippel et al., in prep).

We also require a complete taxonomy of landmark types in order to sufficiently integrate them into route planning systems. For example, while intersections may serve as point-like landmarks in the way buildings do for current approaches (e.g. Raubal & Winter, 2002), there are features in an environment that may function as linear or area-like landmarks (cf. Richter & Klippel, 2005), whose addition greatly extends options to integrate further conceptualizations of actions in route following.

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