Route Direction Structure Diagrams*

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Abstract

Route directions are a window to people's mental representation of space. They highlight problems in conceptualizing a space, for example, areas that are complex and difficult to grasp. Analyzing the structure of route directions helps revealing such difficulties in an environment's conceptualization and allows comparing two different route directions for the same route with respect to their (ease of) conceptualization. In our research, we aim for a formal framework of the interplay between a spatial environment and its conceptualization in wayfinding and, based on this, for generating means of wayfinding assistance that respect for this interplay by, for example, adapting to the route and environment's characteristics. In this paper, we concentrate on so called *Route Direction Structure Diagrams*, which allow to visually analyze route directions' structure on different levels.

Introduction

Space Syntax is concerned with describing and analyzing configured, inhabited spaces (cf., e.g., Bafna, 2003), i.e. with the structure of physical space. In our research, we focus on people's mental representation of space, especially the process of conceptualizing a route in wayfinding (cf. Richter & Klippel, 2005; Klippel, 2003). In that line, route directions, which are instructions generated to guide someone from an origin to a destination, provide one way of externalizing people's mental representation of an environment and, hence, one way to analyze these representations (cf., e.g., Denis, 1997). Route directions are clearly task-oriented; they consist of descriptions of spatial configurations and, especially, of descriptions of actions in space (e.g., Daniel & Denis, 1998). Accordingly, they help to shed light on people's conceptualizations both from a *structural* and a *functional* perspective, i.e. on people's mental representation of configurations of features physically present in a space and the relation of these features to actions performed in that space (cf. Klippel, 2003). To improve their usability, wayfinding assistance systems should respect for the conceptualization process by, for example, adapting to the current context. We use the term context in a general sense to denote "[...]any information that can be used to characterize the situation of an entity" (Dey & Abowd, 2000, p. 3). In our case, this is the current action to take in the current environment; therefore, route directions should account for a route's properties and environmental characteristics (see Richter & Klippel, 2005; Richter et al., 2004).

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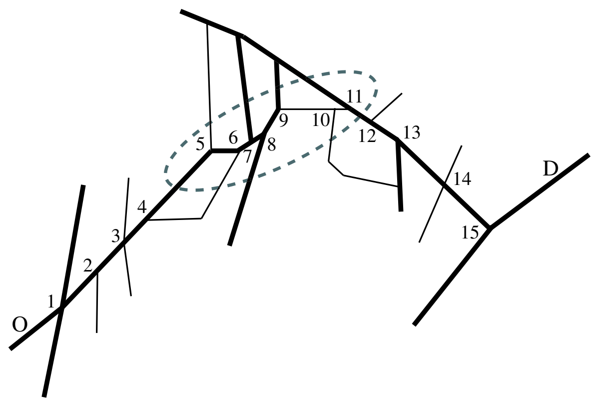

Figure 1: Part of a map showing a city-street network. A sample route leads from origin O to destination D; its decision points are numbered in sequence of traversal. The encircled area demarcates the route's complex part between decision points five to eleven.

Aspects of Route Directions

We consider decision points to be most pertinent in route directions (cf. Daniel & Denis, 1998). Accordingly, in our approach route directions consist of a sequence of single decision point / action pairs or combinations thereof, i.e. a route direction's representation is a sequence of instructions, each composed of one or more decision points with their accompanying actions.

Route directions for a given route may differ in several aspects, the most important ones being: the number and kind of instructions used, i.e. how an action is described in the directions; the reference systems employed in giving directions and changes from one reference system to another; the instructions' level of granularity. Granularity in our approach denotes the degree of abstraction from an explicit, detailed description of a single decision point / action pair (see Richter & Klippel, 2005, for a further discussion of granularity in route directions). An analysis with respect to these aspects helps to judge route directions according to how they support conceptualizing the route they represent. In this paper, we present an approach to visually analyze route directions employing *Route Direction Structure Diagrams*.

Route Direction Structure Diagrams

Route Direction Structure Diagrams (RDSD) are simple, yet powerful diagrams. They consist of two orthogonal axes; the horizontal axis plots a route's decision points, the vertical axis the aspect under examination (see Fig. 2). The decision points plotted along the horizontal axis can either be equally spaced—hence, concentrating just on these points in the analysis—or the spacing between them may reflect their distances in the actual route.

There are three main types of RDSD: the first represents the kind of instructions; the vertical axis plots the direction relations used in a route direction—a relational representation of the action to take at a decision point (Fig. 2a). The second type represents the employed reference systems and changes from one system to another (Fig. 2b); the third type highlights granularity changes in route directions (Fig. 2c). Possible differences in these levels in a route direction's instructions are denoted by labels along the vertical axis; they are called *values* in the following.

For each decision point, the appropriate value is marked with an arrow in the diagram. This arrow points in direction to the next decision point—reflecting the direction of movement—and covers the distance from the current decision point to the next. The arrows can be annotated, for example, to indicate that a landmark is used in connection with the current decision point (Fig. 3a).

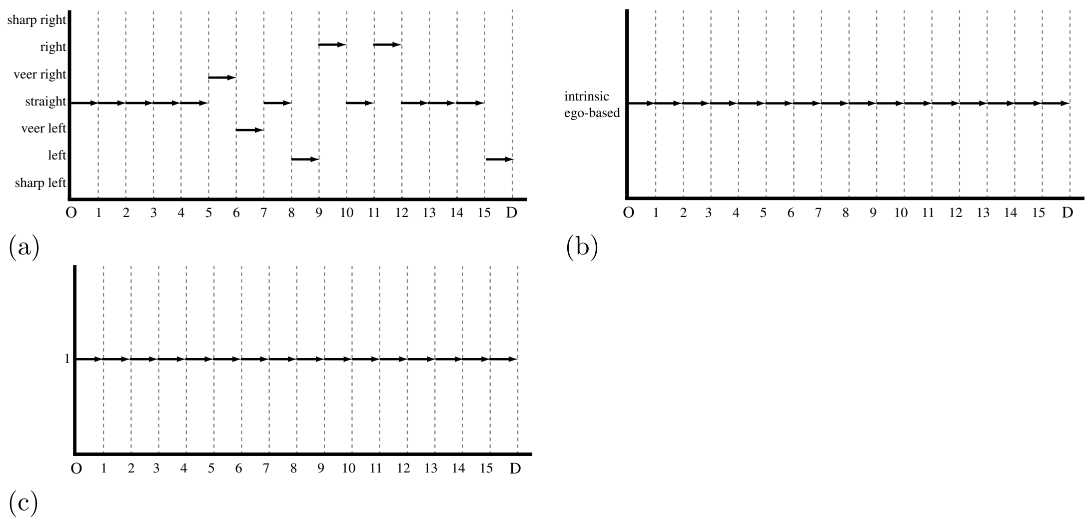

Figure 2: a) Route Direction Structure Diagram for a possible route direction of the route depicted in Fig. 1 employing the direction model elicited in Klippel et al. (2004). b) Type 2 Route Direction Structure Diagram showing the reference systems used in the route direction. In this example, constantly intrinsic ego-based references are used. c) Type 3 Route Direction Structure Diagram showing the level of granularity of the route direction. Here, there is no granularity change; all instructions are given on the lowest granularity level.

Using these diagrams, we can compare route directions visually on different levels and can calculate different (quantitative) measures that evaluate properties of and differences between route directions. Leaps in the diagram, i.e. changes in the values, indicate changes occurring in the route directions. Depending on the diagram type used, these changes need to be interpreted differently: in type 1 diagrams, changes in the values indicate changes of direction, i.e. turns along the route that require a new decision by the wayfinder. In type 2 and 3 diagrams, changes in the values denote changes in employed reference system and level of description, respectively. While this is a change in how the instructions are given, it does not necessarily also involve a change of direction.

Accordingly, the number of leaps and the size of these leaps, i.e. the distance between two values, are exploitable measures. In type 2 and 3 diagrams, for example, a big leap represents a drastic change in the way instructions are given; usually, this denotes a crucial part of a route direction (see below). Additionally, the segment length, i.e. the number of decision points a value holds for, is a meaningful measure. The number of annotations indicates the number and frequency of environmental characteristics employed in the route directions. This is also an important measure as it shows how well the route directions are adapted to the environment route following takes place in: linking actions to landmarks is an important means in providing good, i.e. easily conceptualized route directions (cf. Denis, 1997).

We can further distinguish between local and global measures. This distinction corresponds to intra- vs. inter-diagram measures, i.e. measures that distinguish different parts of a single route direction and those that compare two route directions for the same route. Intra-diagram measures are used to identify complex parts of route directions; many leaps occurring rapidly in the diagram are an indication for a complex spatial situation. This can be seen in Fig. 2a: seven leaps occur between decision points five to eleven indicating a complex sequence of actions, i.e. a complex spatial situation from a functional perspective. Complex functional situations often correspond to complex structural situations as is the case here: decision points five to eleven correspond to the encicled intersections in Fig. 1, which indeed form a complex structure.

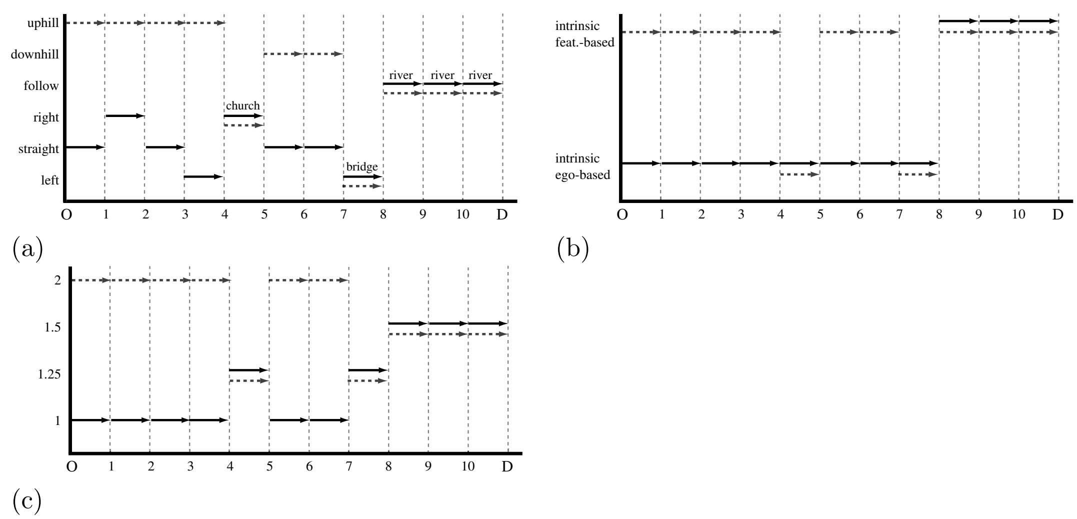

Figure 3: a) Example of two different route directions for the same (fictitious) route. Route direction 1 is marked with bold, route direction 2 with dashed arrows. At decision points four and seven to ten, the arrows are annotated with landmarks that are referenced in both route directions. b) Type 2 Route Direction Structure Diagram showing the reference systems employed in both route directions. In route direction 1, there is a shift from intrinsic ego-based to intrinsic feature-based references at decision point eight. Route direction 2 uses intrinsic feature-based references with two leaps to an intrinsic ego-based reference at decision points four and seven. c) Type 3 Route Direction Structure Diagram showing the level of granularity of both route directions. Generally, route direction 2 is on a higher granularity level than route direction 1.

Inter-diagram measures are used to identify common parts of, differences, and contradictions between two (or more) route directions. Fig. 3 exemplifies this with two sample route directions for a fictitious route. As can be seen in Fig. 3c, route direction 2 is generally on a higher granularity level than route direction 1. Thus, route direction 2 indicates a better understanding of the space's structure, while route direction 1 rather reflects procedural knowledge—or route knowledge in the terms of Siegel & White (1975). Still, looking at what both route directions have in common allows to identify prominent, complex parts of the route. Especially, decision points four and seven seem to be crucial, distinct points along the route; both route directions share the same instruction for them (Fig. 3a). More important, in route direction 2 there occurs a change of reference system at both these points (Fig. 3b) and a rapid change of granularity—from a high-level description to a detailed one (Fig. 3c). This indicates that they are crucial steps for successfully following the route; the according direction change at these points should not be missed.

Conclusions

Route directions are a window to people's conceptualization, i.e. mental representation of space. A structural analysis of route directions, hence, reveals complex parts of a space and differences between route directions for the same route, i.e. differences in people's conceptualization of a space. This analysis can be performed (at least) on three different levels: the direction relations used, the employed reference systems, and the instructions' level of granularity.

In this paper, we present a new method, *Route Direction Structure Diagrams*, for visually analyzing and comparing route directions according to the three levels. Based on this, several intra- and inter-diagram measures can be defined, which identify complex parts of route directions and, accordingly, of a space and point to whether a route direction supports conceptualizing the underlying route. These measures may also be linked to those defined in Space Syntax, in particular to those that relate spatial structure to wayfinding (cf., e.g., Haq & Zimring, 2001). This then allows to compare a spatial structure with the structure of its representation, may be a way to correlate a space's structure to its cognitive complexity, and is a further step of "linking space to action" (Zimring & Conroy Dalton, 2003).

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