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# Cognitively Ergonomic Route Directions

## A Potential Basis for the OpenLS Navigation Service?

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## Overview

**Background**

**Aspect of cognitively ergonomic route directions**

- Landmarks
- Direction concepts
- Granularities and hierarchies

**Conclusions**

**Outlook**

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## Background

Human beings are poorly equipped with spatial abilities (compared to other species)

- bad sense of direction
- poor eye sight
- useless sense of smell

One approach to overcome our limitations is the use of information technology

On the other hand, evolution adapted us as all-rounders

- Human beings suffice in their environments
- The 007 principle (Clark 1989)

The other approach therefore is to learn from human abilities to cope with their deficiencies

- Learning efficiency from deficiency

Requirement for information technology

- Ontologies and cognitive modelling (cognitive engineering)

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## Aspects of Cognitively Ergonomic Route Directions

**Landmarks**

**Direction Concepts**

**Granularities / Hierarchies / Chunking**

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## Landmarks

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## Landmark Definitions

**Theoretical work by:**

- Lynch (1960)
- Siegel & White (1976)
- Presson & Montello (1988)
- Sorrows & Hirtle (1999)
- Raubal & Winter (2002)
- and others

### General Question Addressed

How to integrate landmarks (automatically) into route directions to achieve cognitive ergonomics?

- For example:
- short
  - easy to understand
  - low cognitive load
  - failsafe

### Prerequisite: Structure and Function

Human interaction with the environment can be separated into structural and functional aspects

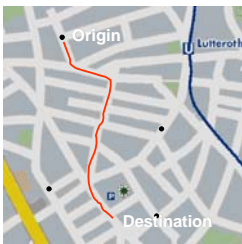
Structural aspects are provided by the environment as such, e.g. intersection

Functional aspects are instantiated by our interaction with the environment

- actions performed in the environment

Both have an influence on the conceptualization and possibly the verbalization

### Route / Path, Structure / Function



Structural perspective



Functional perspective

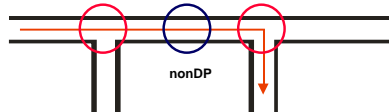


Klippel 2003

### Movement / Event Perspective

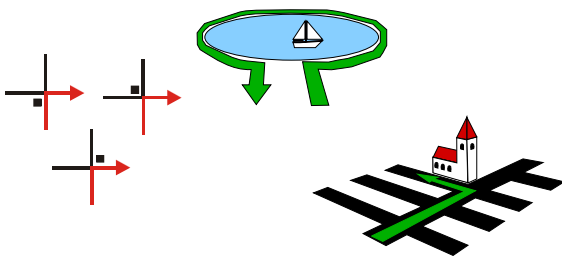
Wayfinding / route following is movement in constraining networks

The primitives (events) of this movements are actions at decision points



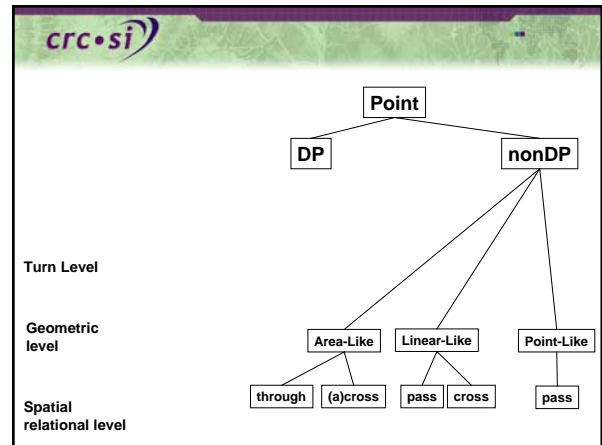
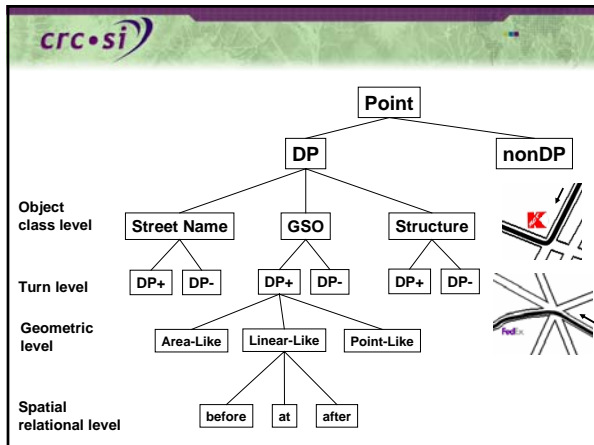
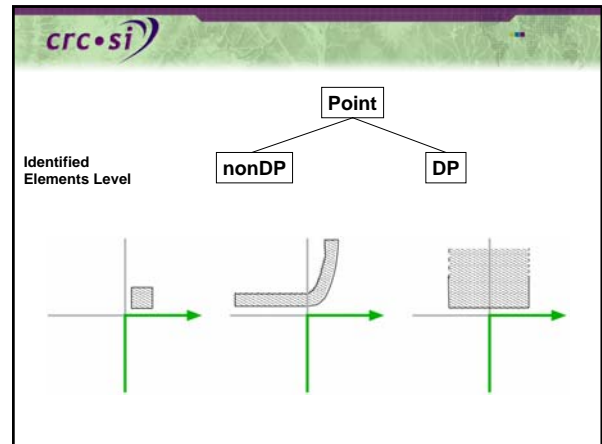
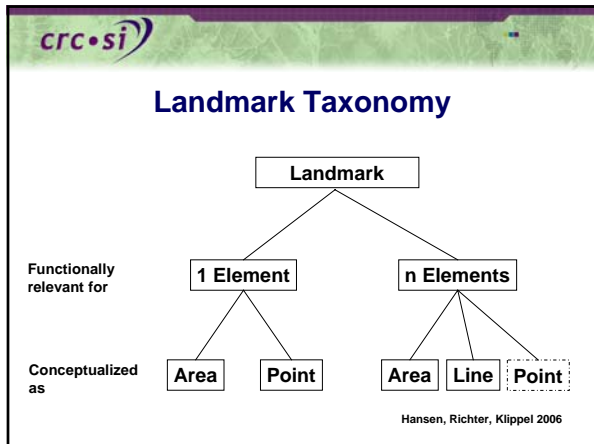
How are these events organized through the presence of a "landmark"?

### Some Examples



### Our Working Definition

A landmark in our approach is an element in the environment with a contextual saliency that allows for structuring our knowledge with respect to movement / wayfinding in that environment.



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## Why is a Fine Grained Distinction Important?

Applicability of projective terms and spatial prepositions

Relating modalities (language and graphics)

A diagram illustrating the relationship between language and graphics. On the left, the words 'left' and 'right' are written next to a vertical line. To the right, there are two diagrams: a street intersection with dashed lines indicating directions, and a 2x2 grid with colored squares (yellow, green, blue, red) and a red dot at the bottom center.

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## Excursus: Spatial Prepositions

Landau/Jackendoff (1993) and others

about, above, across, after, against, along, alongside, amid(st), among(st), (a)round, at, atop, before, behind, below, beneath, beside, between, beyond, by, down, during, for, from, in, inside, into, near, nearby, off, on, onto, opposite, out, out of, outside, over, past, since, through, throughout, till, to, toward, under, underneath, until, up, upon, via, with, within, without,

Compounds  
Away from, Far from, In back of, In between, In front of, In line with, On top of, To the left of, To the right of, To the side of

Verbs ...

**Line Elements**

**Main distinction**

- Whether or not the last element of a chunk is identified

a)

b)

**Line**

```

    graph TD
      Line --> NI[not identifying last DP]
      Line --> ID[identifying last DP]
      NI --> AL1[Area-Like]
      NI --> LL1[Linear-Like]
      ID --> AL2[Area-Like]
      ID --> LL2[Linear-Like]
      AL1 --> along1[along]
      LL1 --> along2[along]
      AL2 --> after1[after]
      LL2 --> after2[after]
  
```

Geometric level

Spatial relational level

**Area**

```

    graph TD
      Area --> NI[not identifying last DP]
      NI --> AL[Area-Like]
      AL --> around[around]
      AL --> through[through]
  
```

Geometric level

Spatial relational level

**Landmark Taxonomy**

**The Data Model**

All types of landmarks defined in our data model are derived from an abstract parent type comprising all basic information about a landmark

Different types of landmarks are used in a polymorphic way

Any type of landmark at the same place in an instruction can be used without the need of specifying which concrete type of landmark to use beforehand

Based on the abstract parent type, all other types are developed according to the [taxonomy of landmarks](#)

**Class tree of the types of landmarks used:**

```

    graph TD
      AbstractLandmarkType --> AbstractElementLMType
      AbstractLandmarkType --> AbstractGlobalLMType
      AbstractLandmarkType --> AbstractElementLMType2[AbstractElementLMType]
      AbstractElementLMType --> AbstractPointLMType
      AbstractElementLMType --> AreaLMType
      AbstractPointLMType --> NonDPPLMType
      AbstractPointLMType --> AbstractDPPLMType
      AbstractDPPLMType --> GSOLMType
      AbstractDPPLMType --> StreetnameLMType
      AbstractDPPLMType --> StructureLMType
      AbstractElementLMType2 --> AreaLMNTType
      AbstractElementLMType2 --> AbstractLineLMType
      AbstractLineLMType --> NonIdentifyingLLType
      AbstractLineLMType --> IdentifyingLLType
  
```

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### XLS Example

```

<xls:Maneuver xsi:type="xls:ManeuverType" actionType="
Turn" id="m1" directionOfTurn="Right" junctionType="
Intersection" >
<xls:ManeuverPoint>
<gml:pos>14.0 4.0</gml:pos>
</xls:ManeuverPoint>
<xls:JunctionCategory xsi:type="
xls:StandardIntersectionType" TurnDirection="right"
>
<xls:RouteBranch StreetName="Berckstrasse">
<xls:Angle uom="degree">90</xls:Angle>
</xls:RouteBranch>
<xls:RouteBranch StreetName="Riensberger_Strasse"
>
<xls:Angle uom="degree">270</xls:Angle>
</xls:RouteBranch>
<xls:RouteBranch StreetName="Leher_Heerstrasse">
<xls:Angle uom="degree">0</xls:Angle>
</xls:RouteBranch>
</xls:JunctionCategory>
<xls:OneElementLandmark xsi:type="xls:GSOLMType" Num=
"Horners_Kreuz" SpatialRelation="after" >
<xls:Description xsi:type="
xls:LMDescriptionExampleType"></xls:Description>
<xls:PointPosition>
<gml:pos>12.0 2.0</gml:pos>
</xls:PointPosition>
</xls:OneElementLandmark>
<xls:PreviousSegment StreetName="Horner_Heerstrasse">
<xls:Distance uom="m">10</xls:Distance>
<xls:TravelTime>100</xls:TravelTime>
<xls:HeadingBox>
<gml:pos>2.0 4.0</gml:pos>
<gml:pos>14.0 4.0</gml:pos>
</xls:HeadingBox>
</xls:PreviousSegment>
</xls:Maneuver>

```

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### To Summarize

- Contextually salient route elements (aka landmarks) organize route knowledge
- It is important to characterize landmarks in a specific context such as movements in networks
- An extended Lynchonian approach seems to be fruitful
- A detailed taxonomy is the basis for a data model that captures aspects of cognitively ergonomic route directions

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### Direction Concepts

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### Extra Geometric Functional Framework

Coventry, Prat-Sala, & Richards 2001  
see also: Coventry & Garrod 2004

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### Structure and Function

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### Structure and Function

veer right      take the second exit      fork right

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## Study 1: Research Question

What is an appropriate model for direction concepts in city street networks

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## Answer

7 direction concepts (plus 'back' sector)

combination of sectors and axes

sectors have different size

'front' and 'back' plane are asymmetric

90 degree 'left' and 'right' demarcate 'front' from 'back' (Franklin et al. 1995)

'left' and 'right' are symmetric

Klippel et al. 2004

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## Study 2: Route directions are specified...

- by making the description more precise
  - "take a sharp right"; "go northwest"
- by establishing spatial contrast to other options
  - "take the one furthest to the right"
- by explicitly mentioning non-intended candidates
  - "don't go straight but somewhat left"
- by applying numerical ordering concepts
  - "second to the right"
- by anchoring actions to landmarks present at an intersection
  - "turn right after the post office"
- by using a structural concept to describe the nature of the intersection
  - "fork right"

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## Towards a Systematic Characterization

The complexity of a route direction to give is determined by

- the structure of the intersection
  - number of branches
  - spatial layout of intersection: typical or deviant angles of branches
- the availability of disambiguating features
  - landmarks
  - salient spatial structures, e.g. T-intersections
- the action to be characterized
  - determines the change of direction
  - distinguishes intended vs. competing objects

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## Empirical Study: Route Directions

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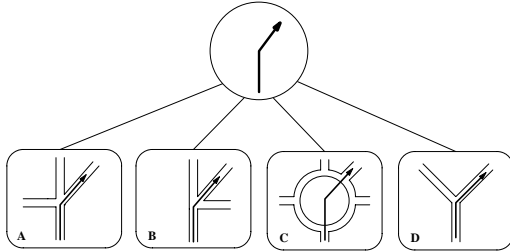
## Analysis of Three Intersections

increasing complexity

Intersection identified by Landmark	A non standard direction change at a non standard intersection	Complex intersection and non standard turn
Unambiguous landmark position	Landmark position unambiguous but after the turn	Additional competing branches
Standard turn at standard intersection		Landmark too far

Klippel et al. to appear

## Structure and Function



## Summary

Direction concepts in city street networks generally are represented as a combination of sectors and axes

Sectors are sized differently

The structure in which the action takes place influences the conceptualization / verbalization

The aim is a systematic characterization of the complexity of an intersection (the interplay of structure and function) and the corresponding conceptualization / verbalization

## Granularities and Hierarchies

### Chunking

Chunking aims on reducing the cognitive load for the traveler by reducing the number of route directions given.

Several directions are subsumed in one single chunk.

Two approaches to form chunks:

- Spatial chunking (Klippel et al., 2003)
- Segmentation (Dale et al., 2003)



### Two approaches

#### Spatial Chunking

Reducing the number of instructions given by subsuming unnecessary and obvious directions in chunks.

Chunked instructions are omitted.

#### Segmentation

Building up a hierarchy on the route directions by segmenting the route and generating a summary for each segment.

Segments can be unfold to access more detailed information.



### Used techniques

#### Spatial chunking based on

- Landmarks




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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks



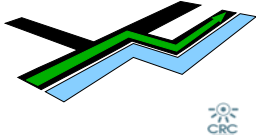
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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks
  - Line-landmarks



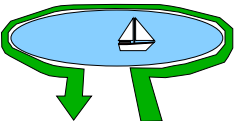
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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks
  - Line-landmarks
  - Area-landmarks




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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks
  - Line-landmarks
  - Area-landmarks
  - Number of chunked DPs



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*Spatial chunking* **Cognitive OpenLS**

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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks
  - Line-landmarks
  - Area-landmarks
- Number of chunked DPs

**Segmentation based on**

- Road-hierarchy



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### Used techniques

**Spatial chunking based on**

- Landmarks
  - Point-landmarks
  - Line-landmarks
  - Area-landmarks
  - Number of chunked DPs

**Segmentation based on**

- Road-hierarchy
- Point-landmarks





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## Combination of both approaches

A basic description of a route consists of a sequence of instructions for each single decision point.


Elementary instructions → 

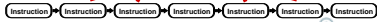



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## Combination of both approaches

The amount of the instructions given can be reduced by applying the techniques used for spatial chunking.

Chunking of obvious instructions → 


Elementary instructions → 





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## Combination of both approaches

On the route directions with the chunked instructions the techniques used for segmentation can be applied.

Segmenting the route → 

Chunking of obvious instructions → 


Elementary instructions → 





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## Combination of both approaches

➔ The result are directions structured hierarchically with levels of different granularity.

Segmenting the route → 

Chunking of obvious instructions → 


Elementary instructions → 



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## Requirements

What is required to chunk automatically route directions?




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## Requirements

What is required to chunk automatically route directions?

This depends on the chunking technique used.



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## Requirements

**What is required to chunk automatically route directions?**

This depends on the chunking technique used.

But in general the underlying data model must

- provide information about the end of the chunk,
- provide the subsumed information and
- allow for building up a hierarchical structure.





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## Integrating chunking in OpenLS

**General data structure:**

An instruction in OpenLS describes the action required at a decision point and at the previous route segment.

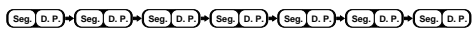




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## Integrating chunking in OpenLS

**General data structure:**

A route consists of a sequence of instructions.

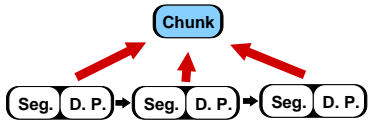




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## Integrating chunking in OpenLS

**Data structure extended for chunking:**

A new data type representing chunks is introduced, which subsumes a sequence instructions.

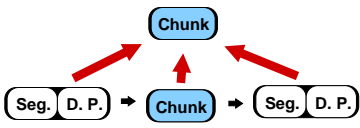




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## Integrating chunking in OpenLS

**Data structure extended for chunking:**

The data types for instructions and chunks are derived from the same parent type. Therefore, chunks can subsume chunks.

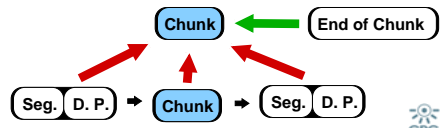




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## Integrating chunking in OpenLS

**Data structure extended for chunking:**

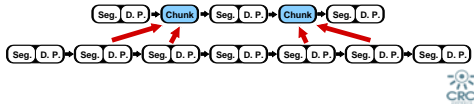
To describe a chunk sufficiently additional information about the end (e.g., a landmark) of the chunk is necessary.

## Integrating chunking in OpenLS

### Data structure extended for chunking:

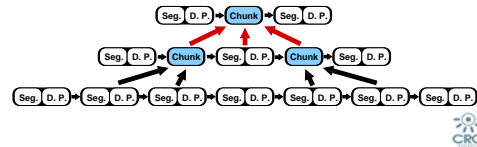
Route consists now on the lowest level of a sequence of instructions and on all higher levels of a sequence of instructions and chunks.



## Integrating chunking in OpenLS

### Data structure extended for chunking:

On the higher levels even chunks are subsumed.



## Overall Summary

Three aspects make route direction cognitive adequate

- Landmarks
- Direction concepts
- Granularities and hierarchies (chunking)

Results from behavioral (cognitive) studies can be used as a basis for a data model

This data model is a prerequisite to cognitively ergonomic route directions

## Ongoing Work

Proof of concept implementation based on data model

From a landmark taxonomy to a landmark ontology with an extensive treatment of linguistics concepts

Technical Report (available next week) that details the complete specification

Integrate this work into a framework for hierarchies and levels of granularity in route directions where landmarks are not necessarily present at every route element / decision point

## Outlook

Personalization

Familiarity

A framework for chunking / hierarchies / levels of granularity

Multimodality

- Different means of transportation
- Different means of communication

Thank you!

## References (Selection)

- Hansen, S., Richter, K.-F., & Klippel, A. (2006). Landmarks in OpenLS: A data structure for cognitive ergonomic route directions. In M. Raubal, H. Miller, A. U. Frank, & M. F. Goodchild (Eds.), *GIScience 2006* (pp. 128–144). Berlin: Springer.
- Klippel, A. (2003). Wayfinding Chores. In W. Kuhn, M. Worboys, & S. Timpf (Eds.), *Spatial Information Theory: Foundations of Geographic Information Science, International Conference, COSIT 2003*, Ittingen, Switzerland, September 24–28, 2003, Proceedings (pp. 320–334). Berlin: Springer.
- Klippel, A., Richter, K.-F., Barkowsky, T., & Freksa, C. (2005). The cognitive reality of schematic maps. In L. Meng, A. Zipf, & T. Reichenbacher (Eds.), *Map-Based Mobile Services - Theories, Methods and Design Implementations*, Springer Geosciences, (pp. 57–71). Berlin: Springer.
- Klippel, A., & Winter, S. (2005). Structural saliency of landmarks for route directions. In A. G. Cohn (Ed.), *Vol. 3693. Spatial Information Theory, International Conference, COSIT 2005, Ellipticville, NY, USA, September 14–18, 2005; Proceedings* (pp. 347–362). Berlin: Springer.
- Klippel, A., Tappe, H., Kulik, L., & Lee, P. U. (2005). Wayfinding chores - A language for modeling conceptual route knowledge. *Journal of Visual Languages and Computing*, 16(4), pp. 311–329.
- Klippel, A., Dewey, C., Knauff, M., Richter, K.-F., Montello, D. R., Freksa, C., & Loeliger, E.-A. (2004). Direction concepts in wayfinding assistance.: Workshop on Artificial Intelligence in Mobile Systems 2004 (AIMS'04) (pp. 1–8).
- Richter, K.-F., & Klippel, A. (to appear). Before or after: Prepositions in spatially constrained systems. In T. Barkowsky, C. Freksa, M. Knauff, B. Krieg-Brückner, & B. Nebel (Eds.), *Spatial Cognition V*. Berlin: Springer.
- Richter, K.-F., & Klippel, A. (2005). A model for context-specific route directions. In C. Freksa, M. Knauff, B. Krieg-Brückner, B. Nebel, & T. Barkowsky (Eds.), *Spatial Cognition IV. Reasoning, Action, Interaction, International Spatial Cognition 2004, Frauenchiemsee, Germany, October 11–13, 2004, Revised Selected Papers* (pp. 58–78). Berlin: Springer.

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