Overview

- Goal scenario of project A1-[RoboMap]
  - Different subproblems require the integration of quantitative and qualitative information
  - Safety requirements(I4-[SPIN]) and shared control(I3-[SharC])

- RouteGraph as an integrative data structure
  - Focus on a generic Implementation together with a formal Specification
  - RouteGraph exchange formats

- Examplary RouteGraphs
  - based on a navigation algorithm
  - cyclist observation

- Conclusion, future work
Goal scenario - motivation

• Wheelchair as an autonomous vehicle, processing spatial knowledge from...
  • sensor data
  • speech input
  • pre-existing maps
Goal scenario - tasks

- Map abstraction and interpretation
  - Use of sensor based mapping algorithms for indoor robot navigation
  - Abstraction of pre-existing maps to RouteGraphs
  - Realtime RouteGraph generation and interactive manipulation
Goal scenario - tasks

- RouteGraph augmentation
  - Natural language statements about spatial relations
  - Combining qualitative and quantitative information for navigation
  - Merging RouteGraphs from different sources
Goal scenario - collaboration

- I4-[SPIN]
  - Formal specification of RouteGraph concepts using CASL
    - Architectural specifications such as „implementation units“
    - Basic specifications like „axioms“ or „data type constructs“
  - Allows tool-supported reasoning and consistency checks

```
Spec Place =
  sort Refsystem, RefPosition
  free type Place::=place(
    refSystem: RefSystem;refPosition: RefPosition)
  ...
```
Goal scenario - collaboration

• I3-[SharC]
  • Providing formal descriptions of natural language dialog
    • XML-like representation of instructions with the perspective of full featured dialogs
  • Detection of situations with shared control problems by means of formal specification (CSP)

```xml
<GoalInstruction kind="drive">
  <GoalObject kind="cube">
    <RelativePosition orientation="behind">
      <SpatialObject kind="box"/>
    </RelativePosition>
  </GoalObject>
</GoalInstruction>
```
RouteGraph\(^1\) as an integrative data structure

- Terminology
  - Kind
  - Place
  - Reference Position
  - Reference System
  - Route Segment
  - Entry
  - Exit
  - Course
  - Route
  - Transition
  - RouteGraph Layer
  - RouteGraph

\(^1\) [Werner, Brückner, Herrmann] „Modelling Navigational Knowledge by Route Graphs“
RouteGraph as an integrative data structure

- Relations to previous work (Spatial Semantic Hierarchy²)

² [Kuipers et al.] „The Spatial Semantic Hierarchy“
RouteGraph as an integrative data structure

- RouteGraph API
  - C++ implementation
  - Generic by means of consequential use of the bridge-pattern
RouteGraph as an integrative data structure

- RouteGraph API
- HTML-based documentation simplifies porting to other platforms
RouteGraph as an integrative data structure

- RouteGraph exchange formats
  - XML – object tree
  - current tools supporting RouteGraph.XML:
    - XMLSpy (xml-viewer)
    - Matlab (content visualization)

```xml
<Place>
  <Id>3</Id>
  <Kind>KI_ROLLAND_METRIC</Kind>
  <ReferencePosition>
    <Id>1</Id>
    <Kind>KI_ROLLAND_METRIC</Kind>
    <pos.driving_speed>0.000000</pos.driving_speed>
    <pos.heading>0.000000</pos.heading>
    <pos.steering>0.000000</pos.steering>
    <pos.steering_speed>0.000000</pos.steering_speed>
    <pos.x>0.000000</pos.x>
    <pos.y>0.000000</pos.y>
  </ReferencePosition>
</Place>
```
RouteGraph as an integrative data structure

- RouteGraph exchange formats
- daVinci – term representation
RouteGraph as an integrative data structure

- RouteGraph exchange formats
- daVinci – example
Examplary RouteGraph

- Essential navigation algorithms (1): Steering with „Continuous Curvature Paths“\(^3\)
  - Basic strategy for driving in obstacle free space
  - CCPs consist of circular arcs, clothoids and line segments
  - CCPs correspond to the nonholonomic properties of a car-like robot

\(^3\) [Fraichard, Scheuer] „Planning continuous-curvature paths for car-like robots“
Exemplary RouteGraph

- Essential navigation algorithms (2):
  Navigating with CCPs and Voronoi Diagrams

  - Extraction of navigational knowledge from sensoric input
  - OpenGL hardware allows fast computation of voronoi faces
  - Edge detection via convolution filter
  - Solution of A* search in pixel space combined with start- and goalCCT

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Examplary RouteGraph

- Essential navigation algorithms (3):
  Lack of navigational knowledge when input is limited to real sensors

- Virtual laser scanner as an example for abstracting pre-existing maps to RouteGraphs
Using RouteGraphs as an Appropriate Data Structure for Navigational Tasks

Christian Mandel, A1-[RoboMap]

Examplary RouteGraph

Rolland CCT-PathPlanner
Using RouteGraphs as an Appropriate Data Structure for Navigational Tasks

Christian Mandel, A1-[RoboMap]

Exemplary RouteGraph

Cyclist Navigation

GPS Hand-Keyboard
Conclusion, future work

- RouteGraph as an agent independent structure for navigational tasks

- Current implementation supports metrical and topological layers
  - Integration of reasoning calculus within the topological layer

- Investigation of new Layers (dialog-layer, ...)

- Extraction of spatial knowledge from pre-existing maps (virtual laser scanner, ...)
  - Detection and Classification of architectural features within blueprints

- Support of RouteGraph-porting to other platforms and domains
Thank You ;-)