Reasoning About Large Places

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Abstract. To support natural interactive way-finding tasks, computational formalisms of places are needed. In this extended abstract we present the idea of conceptual route graphs, which represent places using decision points, local route graphs and directional relations for modelling places in different way-finding situations. The application of formal spatial representations allows formal spatial reasoning about places, in particular deductions with qualitative calculi.

1 Small Places as Decision Points in Route Graphs

A framework for Conceptual Route Graphs has previously been presented, based on Route Graphs and the Double Cross Calculus [4]. In this approach, places and route segments are represented as nodes and directed edges of a route graph; routes are composed of consecutive route segments. Places act as decision points for the choice of a route segment, emanating from this place, to follow next in a route. When integrating several routes into a route graph, overlapping route segments are identified whenever their constituent places can be integrated. Thus *place integration* is a crucial notion: the orientation of outgoing route segments is computed relative to the *inherent* orientation of a place (analogously for incoming route segments); upon integration, this orientation is re-adjusted. The orientation of an outgoing from an incoming route segment is then computed as "the sum" of their orientations (relative to the inherent orientation of the place).

In practice, one would most likely define the inherent orientation of a place by reference to a salient landmark (e.g. "oriented towards the city hall"). When integrating the intermediate place of two consecutive route segments with a defined place in a route graph, the target/source orientation of the incoming/outgoing route segment is re-adjusted relative to the orientation of the defined place ("when incoming/outgoing, which orientation do I have w.r.t. the city hall?").

The (orientation at the) source and target places and the intermediate route segment can be taken as an element for the Double Cross Calculus (DCC) [1, 8], to reason about orientations of two consecutive route segments by composition in DCC.

2 Large Places with Local Route Graphs

Here, we extend the above notions for "small" places, suitable for reasoning about decision points in a network, e.g. in a corridor-like situation, with a framework

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for “large” places that have a sizable extent, such that, to reach an outgoing from an incoming route segment, one has to “cross” the (supposedly vacuous) place, walk around its perimeter (as for a traffic circle), or do some even more complicated micro-navigation. First, we consider large places which cover a well-defined area (that constitutes a region in itself) with a border. We classify such large places according to their accessibility (and resulting navigability), e.g.:

open the area is an open navigable space, allowing cross-cuts;
closed the central area is closed, navigation is only possible around the perimeter (e.g. a traffic circle);
complex navigability is more complex (e.g. a traffic circle with an island, such that navigation around the perimeter permits occasional access to the island, which is a nested open space allowing cross-cuts).

In either case we may represent the large place by a local route graph that refines the place (as seen at a higher level of abstraction) into a route graph with a “higher resolution” for micro-navigation; incoming and outgoing route segments are connected to this local route graph such that it allows a transition from each incoming to every outgoing route segment (this condition has been specified for route graph refinements in [3]).

An open place is represented by a route graph that includes all possible connections of incoming to outgoing segments cutting across the open space; a closed place by a linear route graph representing the perimeter (mono- or bi-directional). The dynamic situation of a person being “in the middle” of an open space can be handled by a (dynamically moving) extra place representing the pose (position and orientation) of this person, with route segments connecting to (incoming and) outgoing segments.

3 Direction Relations for Large Places

As an alternative to route descriptions, human way-finding tasks often specify locations of salient landmarks in an open space. A recent experiment showed that such *scene descriptions* improve visualization, memorization and way-finding success, in an indoor environment [6]. Combining route descriptions with location specifications is required for navigation tasks in an environment containing large places where route graphs do not exist or are less explicit: from an incoming route ending at an exit location in the perimeter of a large place, navigation will be continued using a place description leading to an entry location of an outgoing route segment.

A place description comprises landmarks and directional relations. Since DDC is a model of relations between three points, or between a point and a directed route segment, and does not capture relations between objects with spatial extent, new models are needed for the formal representation of directional relations. For example, Goyal and Egenhofer's direction-relation matrix [2], Skiadopoulos and Koubarakis' projection based cardinal directional relations [7], or Kurata and Shi's heterogeneous cardinal direction [5] are possible models for representing and deducing directional relations between spatial objects.

4 Conclusions

To model places in human or cooperative human-robot way-finding tasks, qualitative maps that integrate route graphs, point-based orientation models and directional models for representing places are needed. Depending on the level of abstraction, a place may be either, a decision point in a route graph, at which reorientation is needed to connect incoming and outgoing route segments; after refinement, a local route graph, which allows a transition from each incoming to every outgoing route segment; or a large open place, where scene descriptions are required to make the local connection.

Extending the conceptual route graph developed in [4] with directional models for place descriptions poses a new challenge. The focus will be on the connection of two route segments conjoined by a large place represented as a detailed conceptual route graph or modelled via a set of directional relations between spatial objects.

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