Hybrid Mapping for Autonomous Mobile Robot Exploration

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Abstract - *Hybrid maps combining several approaches to store robot's interpretation about its working environments are getting popular nowadays. This work deals with a novel approach to hybrid maps that is based on fixed-size interconnected occupancy grids organized in a topological graph. The presented mapping approach is employed in the exploration scenario, where the map is built from scratch and used for both local and global path-planning, and goal selection. Feasibility of the approach has been validated by a set of experiments in the Player/Stage system.*

Introduction

In order to provide autonomous behaviour, robots build their own representation about the operating environment, i.e. a map. Generally, two types of maps are used:

Metric:

- √ accurate geometric description
- √ suitable for path-planning
- × very costly in large environments

Topological:

- √ describes topological relations between observed features
- × not suitable for precise localisation

Combining both, we used a hybrid map:

Hybrid: local fixed-size occupancy grids + global graph

- √ scalable in large environments
- √ supports unstructured environments (grid ≠ room)
- √ cheap path-finding

Map Structure

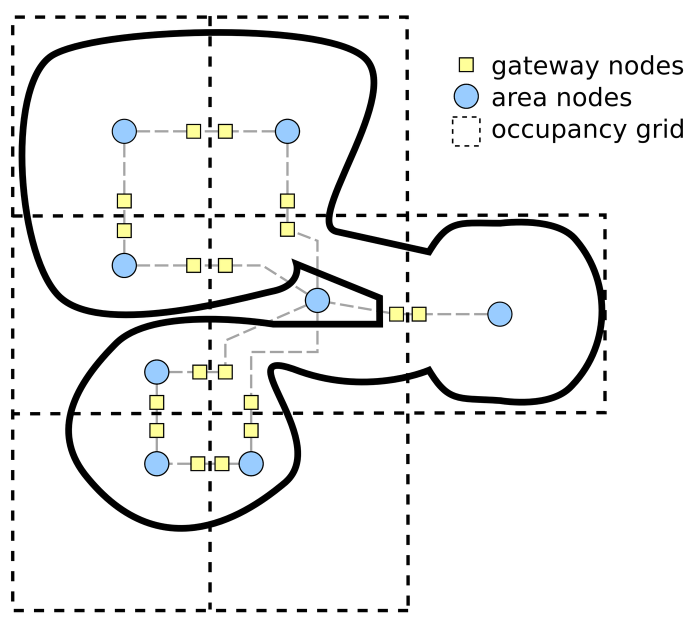
Metric and topological aspect:

Metric: series of fixed-size occupancy grids

- *gateway:* set of contiguous free cells of each border of a grid

Topological: graph with two node-types:

- *area nodes:* distinct topological areas of a given grid
- *gateway nodes:* topological view of metric gateways



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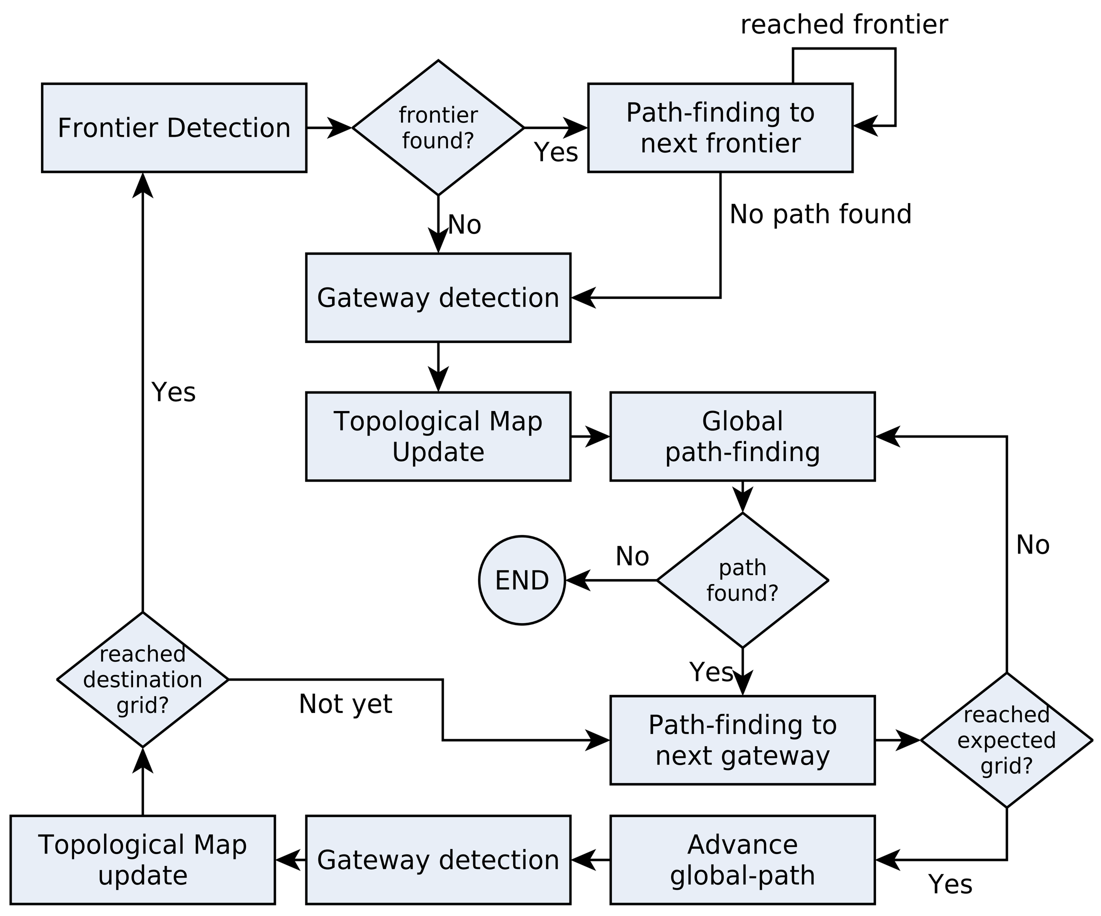
Exploration Method

Local level: path-finding over a local grid

Global level: path-finding over the global graph
To follow the global path → local paths are computed along the way

Path-finding algorithm: *Dijkstra's shortest path*



Gateway Detection

1. For each edge of a grid, the lists of contiguous free cells are constructed
2. Free cell:
   - occupancy probability ≤ treshold
   - require this condition to neighbouring cells perpendicular to the edge, up to a certain distance
     Avoids attempting to traverse a grid when a wall lays on the adjacent grid (invisible to local path-planning)
3. Each metric gateway is associated with a gateway node in the graph

Map Update

Metric Map

- Probabilistic model of sensor data. Information is applied to current grid with a Bayesian Filter
- Update is first performed over a large robot-centered grid and is then applied to the overlapping grids of the map

Topological Map:

1. Local path-finding performed between robot position and each gateway node
   If path is found, nodes are connected (otherwise, they're disconnected)
2. Topological area equivalence is determined
   - Robot always has a notion of *current area node*
   - Upon entering a grid, this node is connected to the gateway node used for entrance
   - For each gateway in the grid, path-finding is performed
     - If the GW node is not associated with an area node, it is connected
     - Otherwise, the current node and the other node are merged

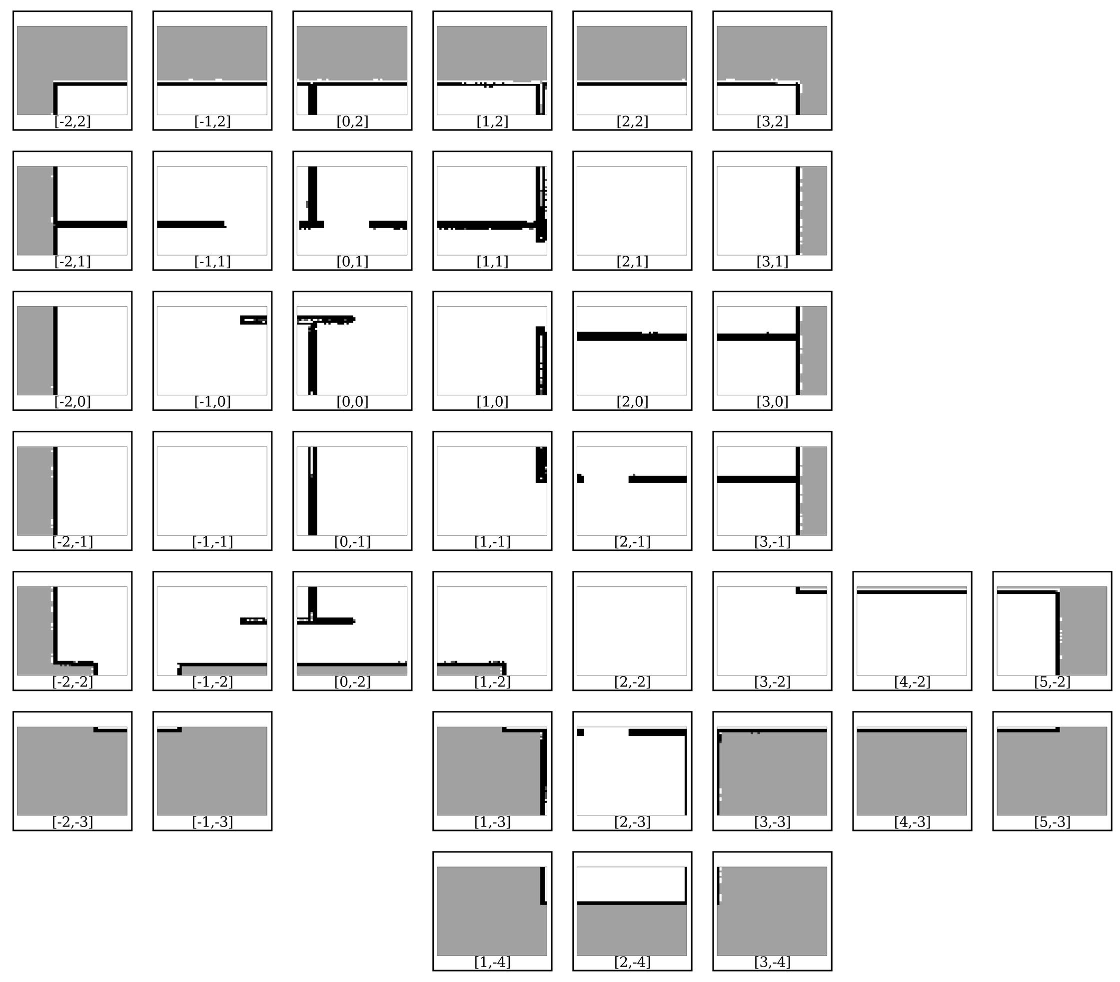
Experiments

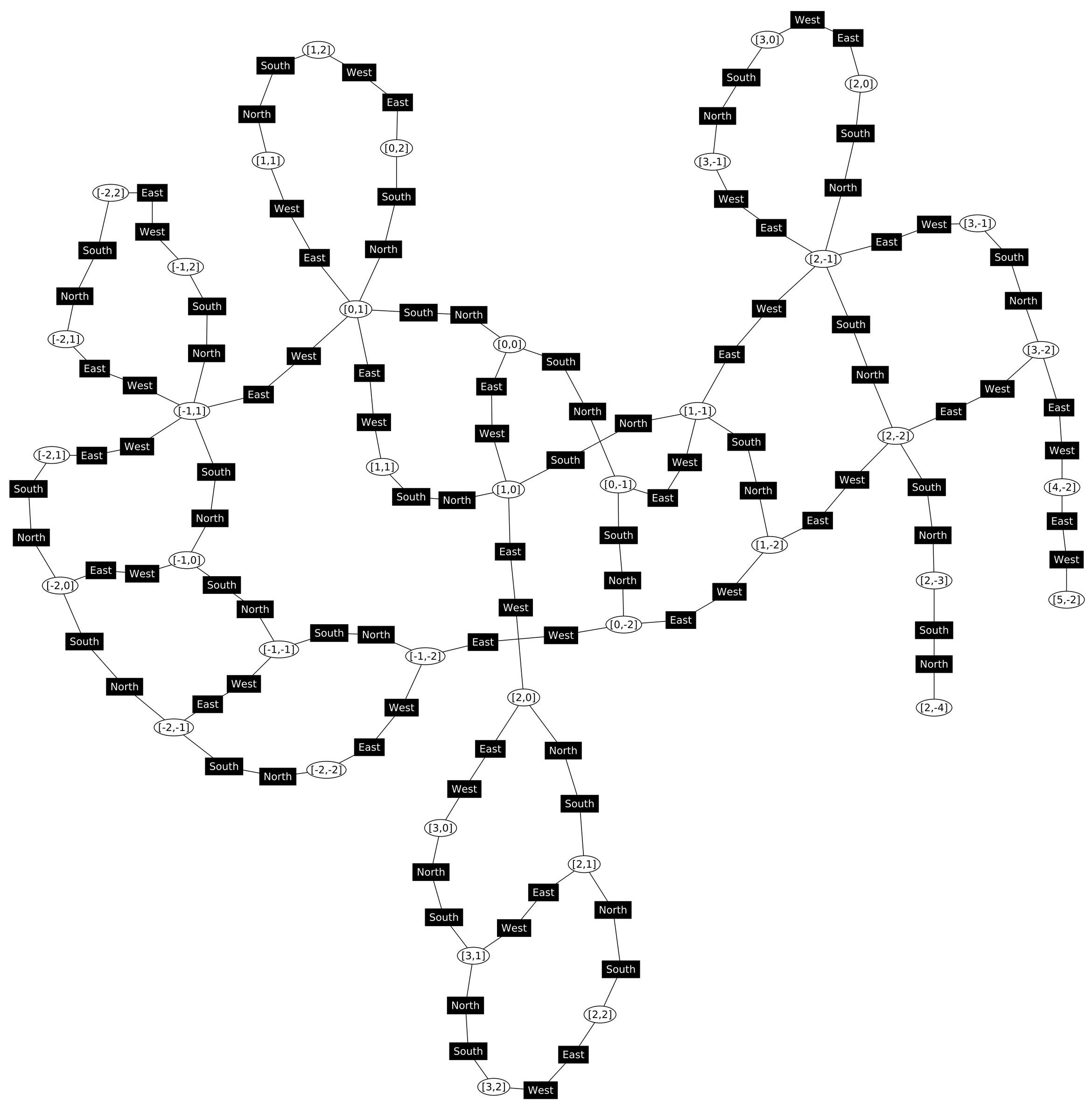
Method was implemented in C++ as a client program for the Player/Stage environment (version 3.0).
Simulation conditions:

Robot: Pioneer 2DX (w/SICK LMS200 laser sensor -180 FOV)

Environment: Several structured and non-structured envinronments were tested, 25×20 meters

Results for a structured office-like area are presented here





Conclusion

- The results show the feasiblity of the approach.
- In contrast to full global metric map:
  - scalability in terms of memory usage
  - supports non-structured environments
  - minimizes path-finding cost without losing accuracy
- In contrast to one grid per-room:
  Unstructured (no rooms) or open areas (big rooms) are not a problem with fixed-size grids