Combining metric and topological navigation of simulated robots

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Introduction

- Mobile robotics – promising development.
- An important component: navigation.
- Former work: occupancy grid method with value iteration.
- Extension with a topological graph.
- Simulation environment: Webots, won in contest 2000.

The problem of navigation

- Simultaneous localization and mapping (SLAM, CML).
- Problems:
  - sensor/motor noise
  - high dimensionality of environment
  - data association
  - changing world
  - real-time solution
  - reliable solution
  - general solution

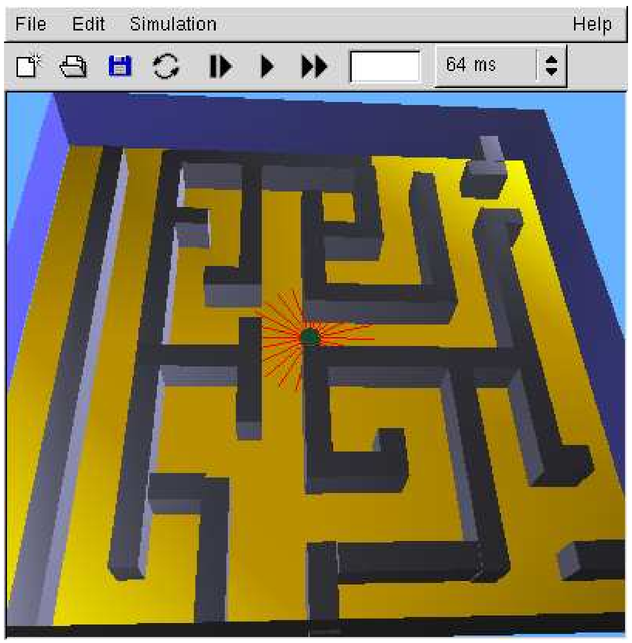
Chronicle / Michael Maloney

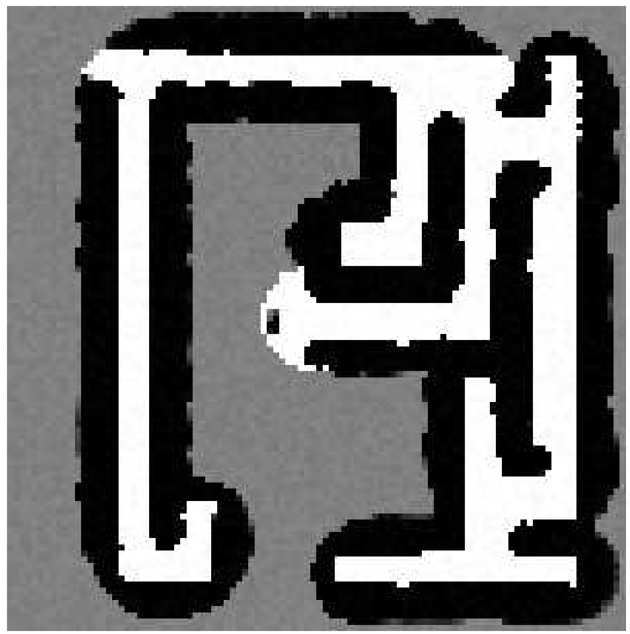
Probabilistic mapping

- Bayes theorem $\left(p(h|D) = \frac{p(D|h)p(h)}{p(D)}\right)$.
- Maximum likelihood map based on data.
- Methods:
  - Kalman filter
  - expectation maximization
  - occupancy grid
  - hybrid approaches
  - object maps
  - DOGMA (dynamic occupancy grid mapping algorithm)

Occupancy grid

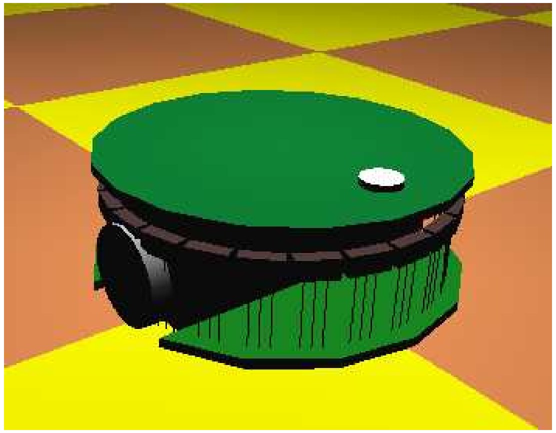
- Stochastic parcelling of plane/space.
- Occupancy probabilities of cells.
- Pros: simple to implement, iterative.
- Cons: independent noise needed, clumsy for navigation.





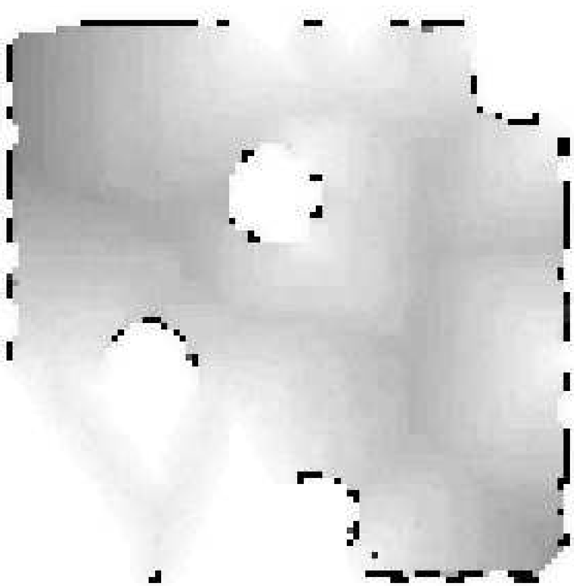
Former work

- Metric navigation for a modified Khepera in Webots presented in CSCS'2002.
- 8 infra-red distance sensors => 24 sharper sonars.
- Important steps:
  - sensor interpretation (calculation of occupancy values in a small environment)
  - integration over time (Bayes theorem)
  - position estimation
  - global grid building
  - exploration (value iteration)



Exploration

- Driving force is needed to urge the robot to explore.
- Value iteration on a cost matrix.
- Cumulative cost of travelling to an unexplored cell.
- Open room with some cylindrical objects.
- Complex maze.

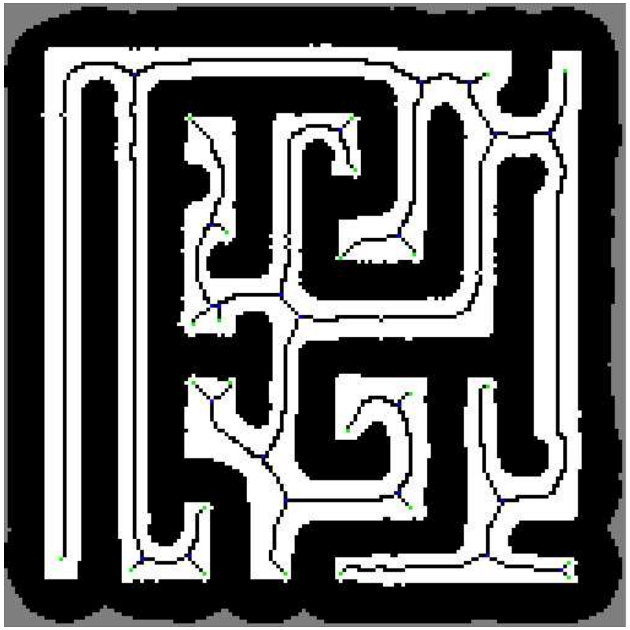


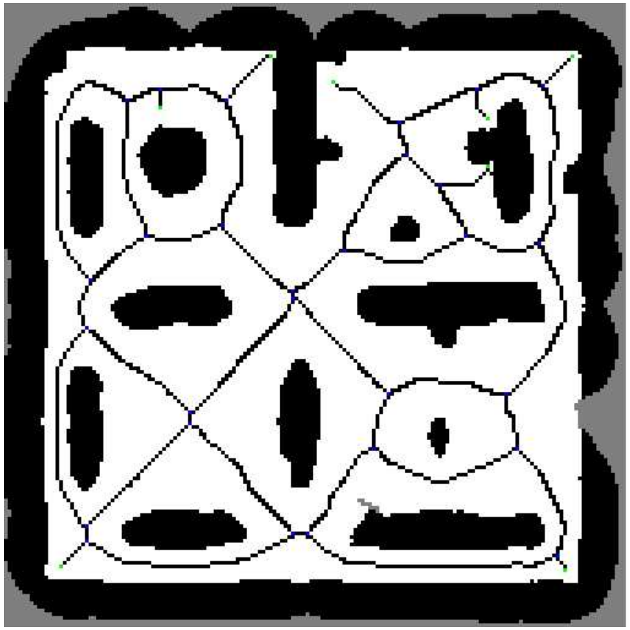
Current work

- Value iteration is a very time-consuming task.
- Exploration direction selection is awkward.
- value iteration => topological graph
- Important steps:
  - skeletonization
  - chaining the skeleton to form edges
  - graph optimization
  - navigation with the graph

Skeletonization

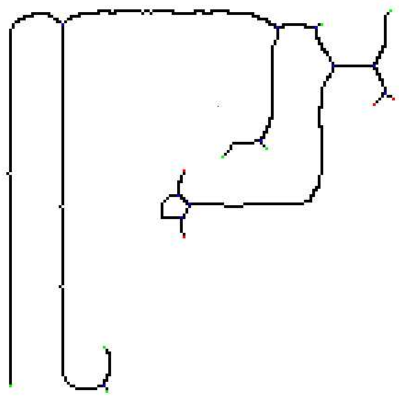
- Skeleton of the explored and unoccupied region.
- An image processing method.
- Thinning: border pixels are deleted successively.
- Topology and morphology are preserved.

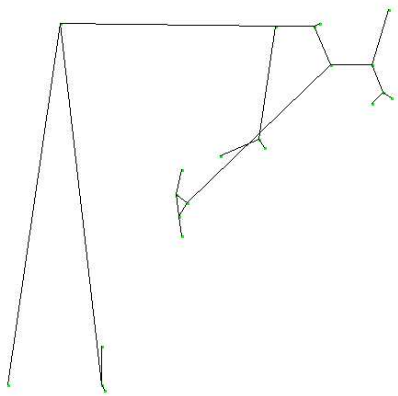




Chaining

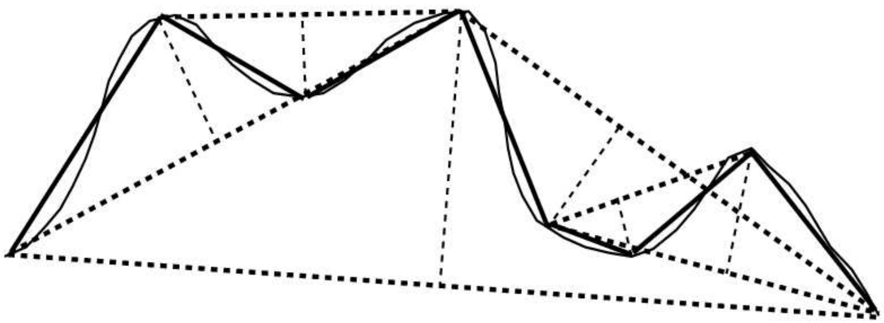
- Skeleton transformation to graph.
- Nodes: where skeleton branches meet, end points.
- Edges: skeleton branches.
- Minor bugfixes of Tombre et al.'s algorithm.





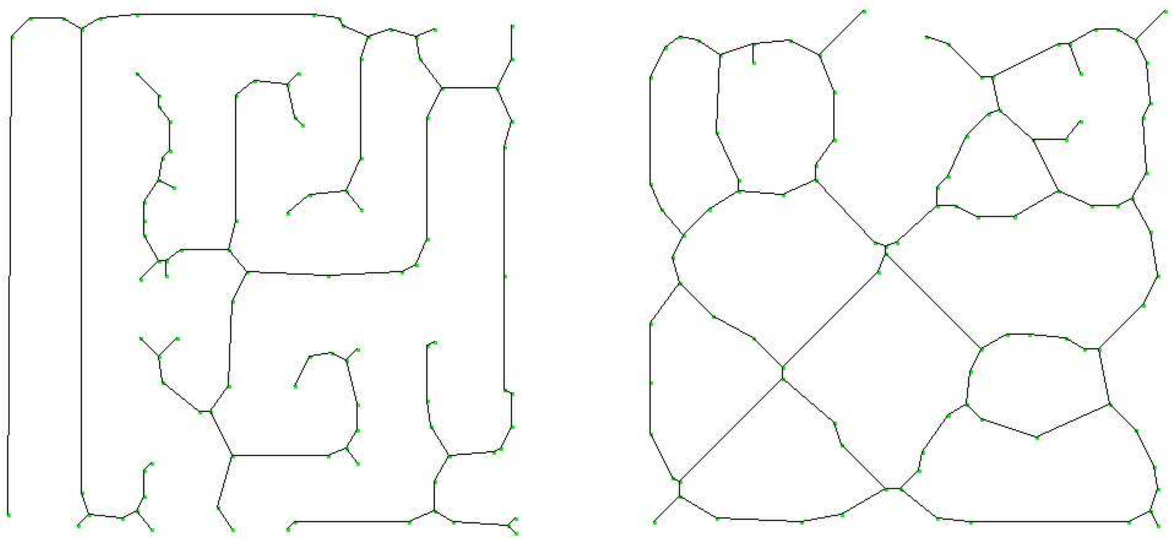
Graph optimization

- Graph is not applicable to navigate.
- Edge splitting for approximation and pruning.
- Rosin and West vs. Wall and Danielsson.
- Accuracy vs. efficiency.

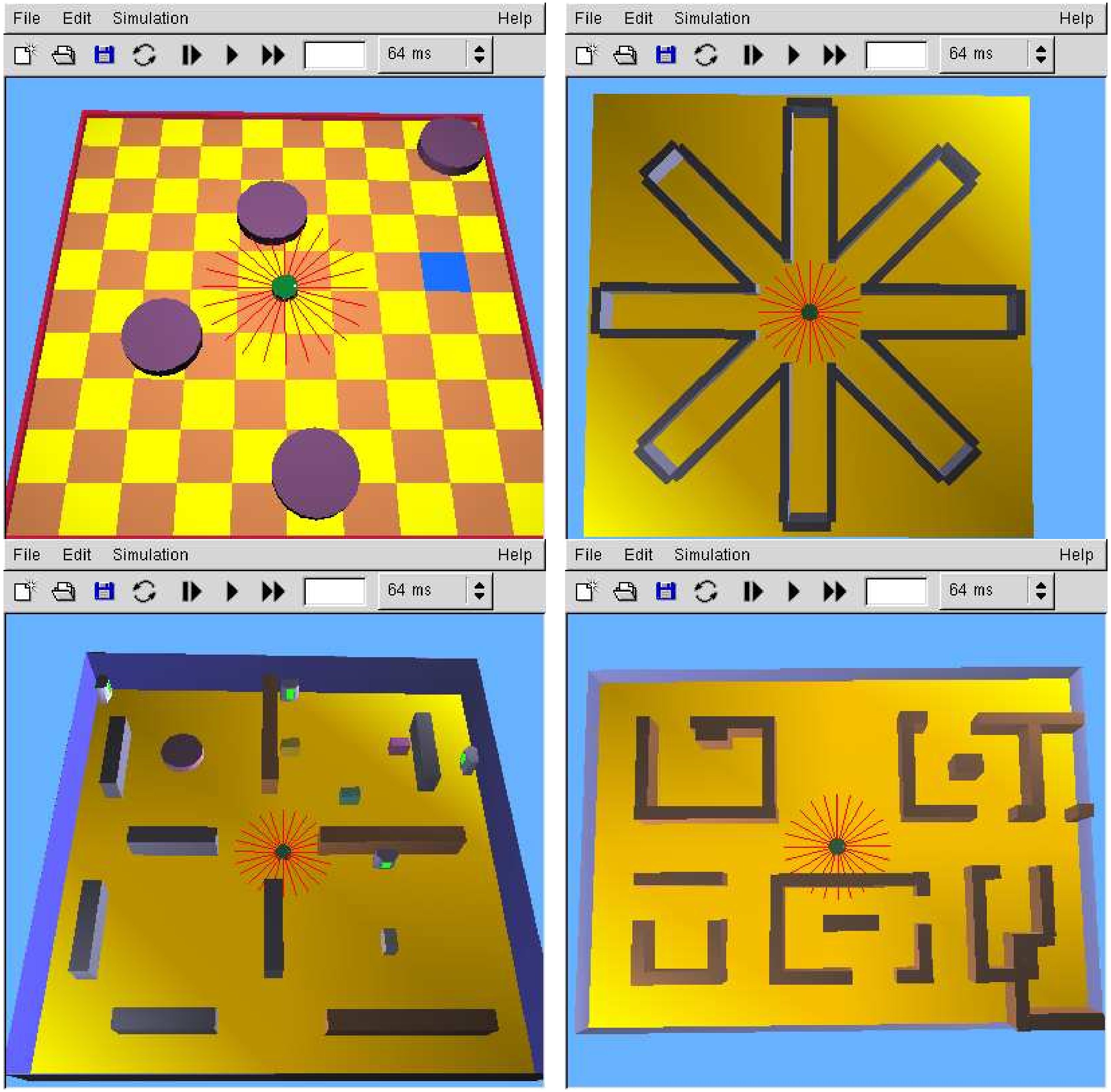


Navigation

- A^* algorithm to explore.
- Shortest path to unexplored from actual pose.
- Normal move module to go ahead.
- Alternation between the modules.



Test environments



Results

Minutes	Value iteration	Graph
Open room	8	6.4
Radial	6.3	6
Office	20	12.4
Maze	22	14.5
AAAI contest	14	11.7
Pixels/nodes		
Open room	12800	50
Radial	11600	20
Office	28900	110
Maze	28900	120
AAAI contest	23700	105

Conclusions

- Topological graph on top of occupancy grid navigation.
- Known algorithms integrated to solve the problem.
- Smaller amount of memory.
- Better total exploration time, more than 20%.
- Help in elongated parts, at connections of large spaces.

Future work

- Testing the algorithms in real robot.
- Integration of new sensor types (video camera).
- Higher level behaviors.
- Partially or fully dynamic elements (doors, people).
- Using position estimation may make the robot fully automate.