DroMOOC

Motion Planning

Advanced level

Sampling-based methods

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ONERA

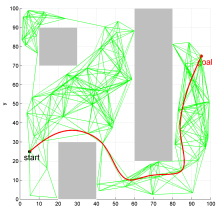
Sampling-based path planning

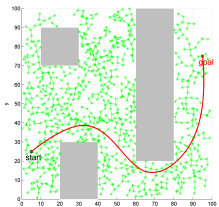
Probabilistic search

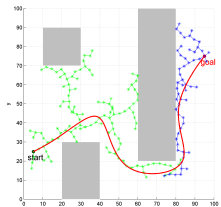
Graph created from randomized requests in configuration space
Collisions checked when adding new nodes
Path found by deterministic search in this graph

Algorithms presented

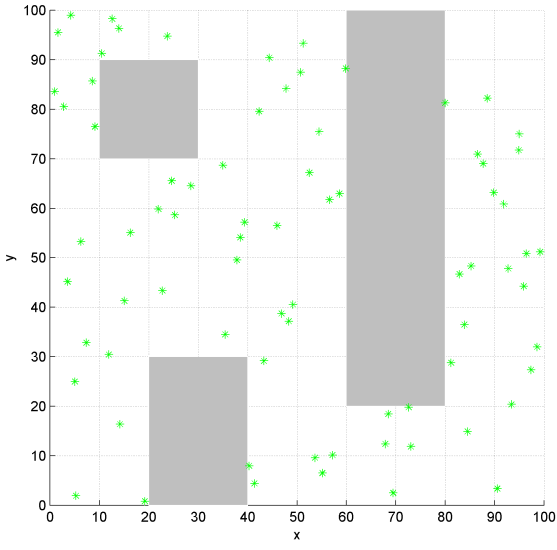
- PRM (Probabilistic RoadMap)
- RRT (Rapidly-exploring Random Tree) and RRT-Connect







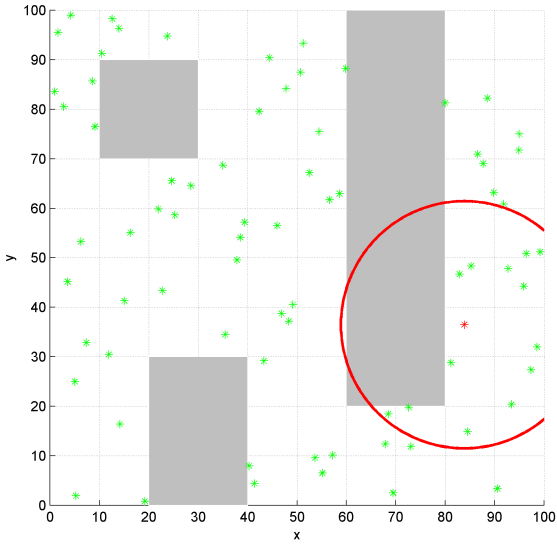
Probabilistic Roadmap (PRM)



Graph construction

- Pick random samples in free space (e.g. uniform, Latin Hypercube)
- For each node, in a specified range: list feasible neighbors of the node

Probabilistic Roadmap (PRM)



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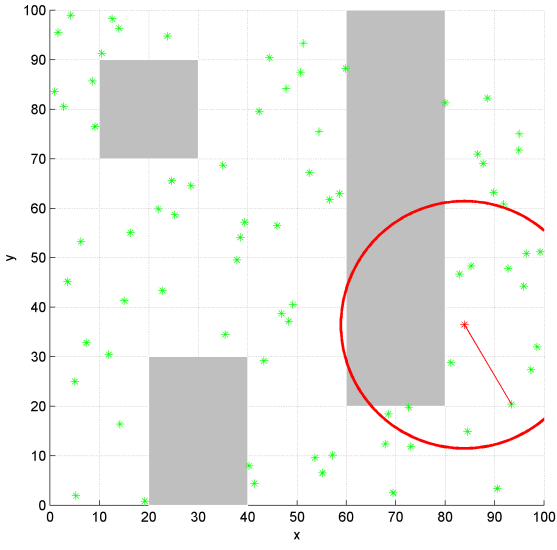

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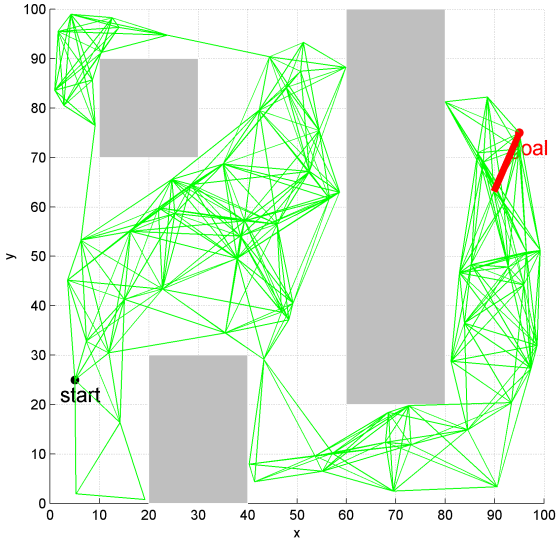
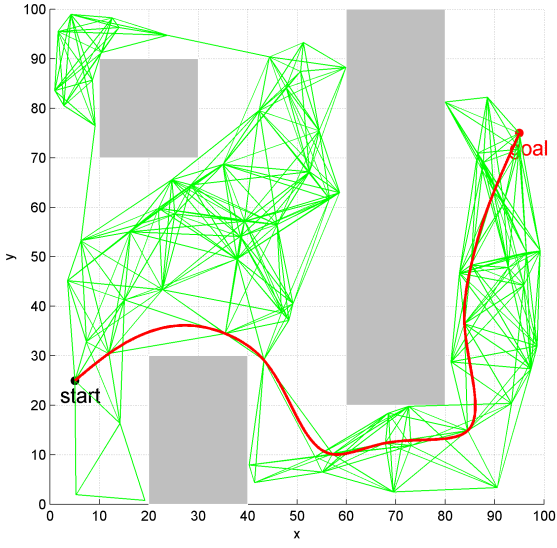


Path finding

Use Dijkstra or A* to find shortest path from start to goal.

Probabilistic Roadmap (PRM)

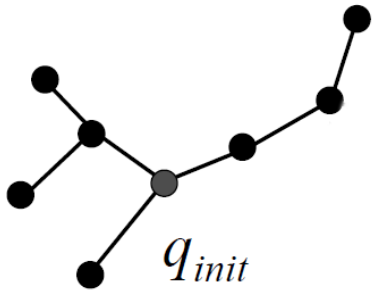


Path finding

Use Dijkstra or A* to find shortest path from start to goal.

Smoothing using a cubic spline

Rapidly-exploring Random Tree (RRT)

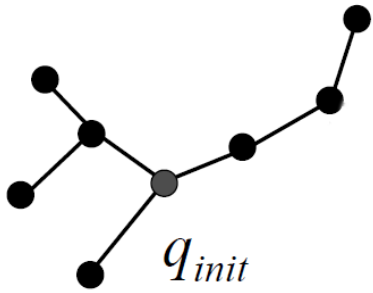


[Kuffner & LaValle , ICRA'00]

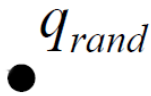
Algorithm

Maintain a tree of nodes, with equal distances

Rapidly-exploring Random Tree (RRT)



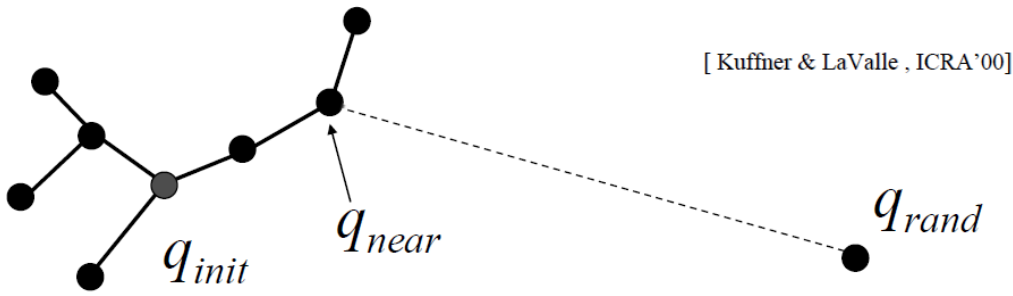
[Kuffner & LaValle , ICRA'00]



Algorithm

Sample a random configuration

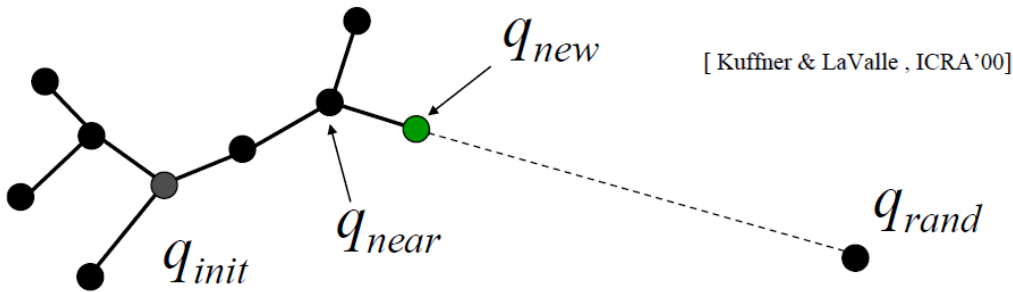
Rapidly-exploring Random Tree (RRT)



Algorithm

Find the nearest node in the tree

Rapidly-exploring Random Tree (RRT)

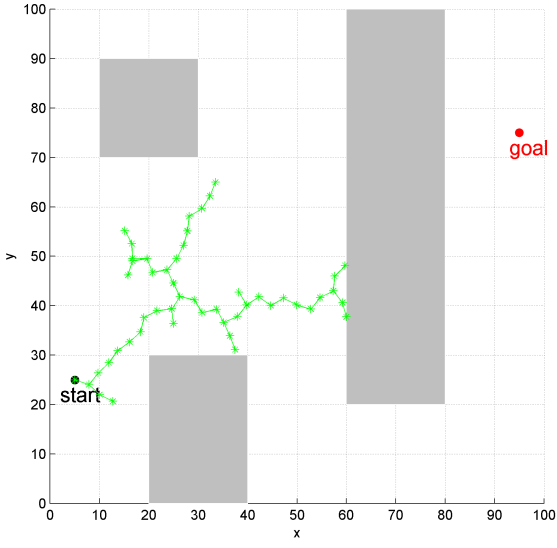


[Kuffner & LaValle , ICRA'00]

Algorithm

Extend the tree towards the target (if no collision) and repeat the operation

Rapidly-exploring Random Tree (RRT)

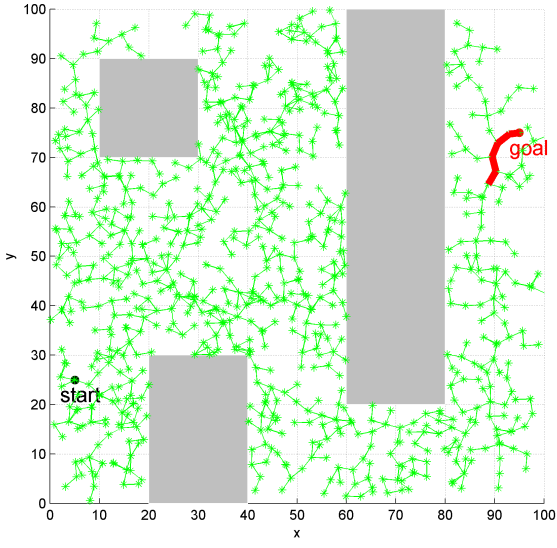


Algorithm

Expand tree until either:

- Predefined number of samples
- Goal reached

Rapidly-exploring Random Tree (RRT)



Algorithm

Expand tree until either:

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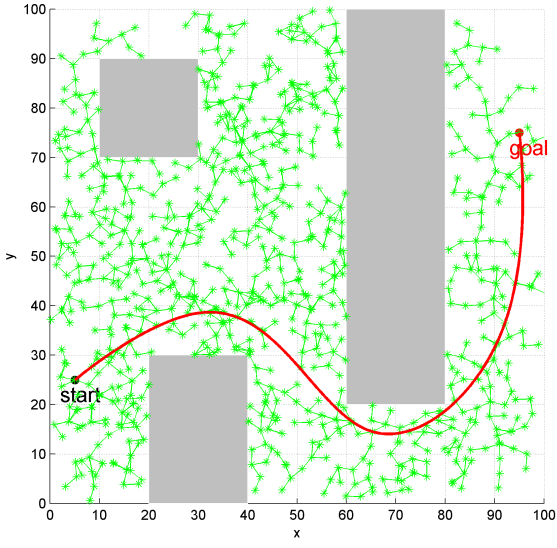
Path: tree query from goal to start

Rapidly-exploring Random Tree (RRT)



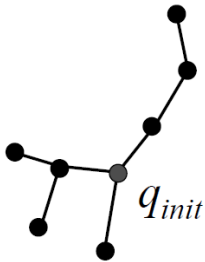
Algorithm

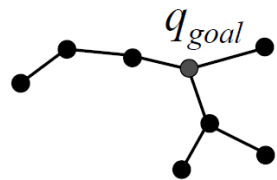
Expand tree until either:

- Predefined number of samples
- Goal reached

Path: tree query from goal to start
Downsampling and spline smoothing (collision risks)

RRT-connect



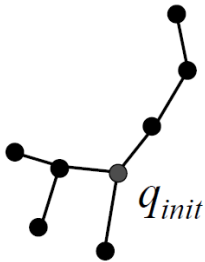


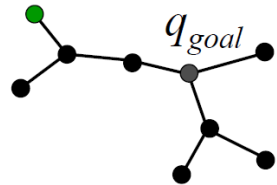
[H. Choset & J. Kuffner, CMU]

Algorithm

Maintain two trees, from start and goal

RRT-connect



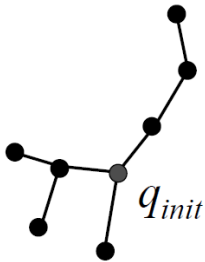


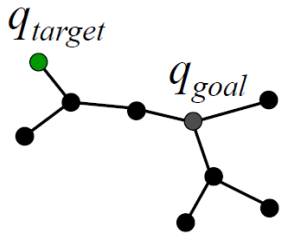
[H. Choset & J. Kuffner, CMU]

Algorithm

Extend one tree using random sample

RRT-connect



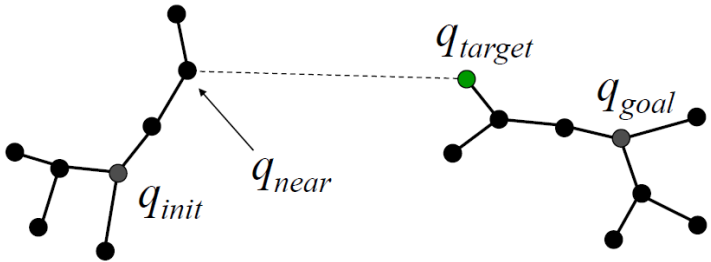


[H. Choset & J. Kuffner, CMU]

Algorithm

The new node is now a target for the other tree

RRT-connect

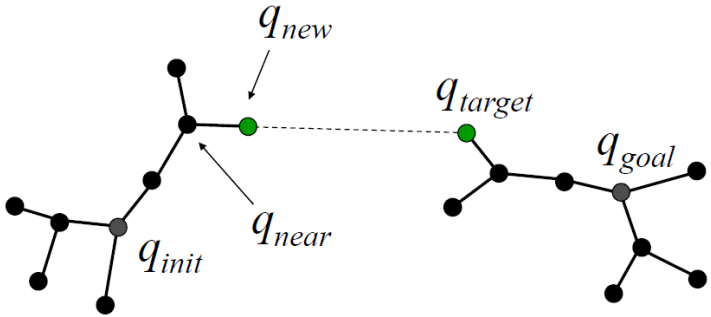


[H. Choset & J. Kuffner, CMU]

Algorithm

Find the nearest node in the other tree

RRT-connect

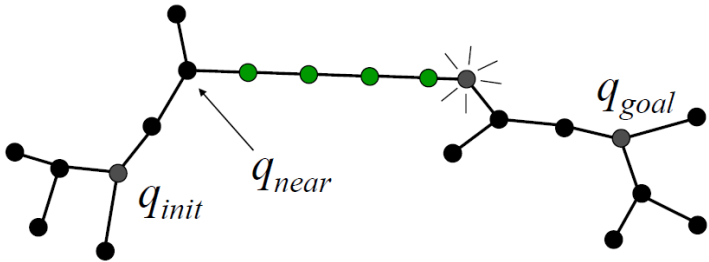


[H. Choset & J. Kuffner, CMU]

Algorithm

Extend the tree towards the target

RRT-connect

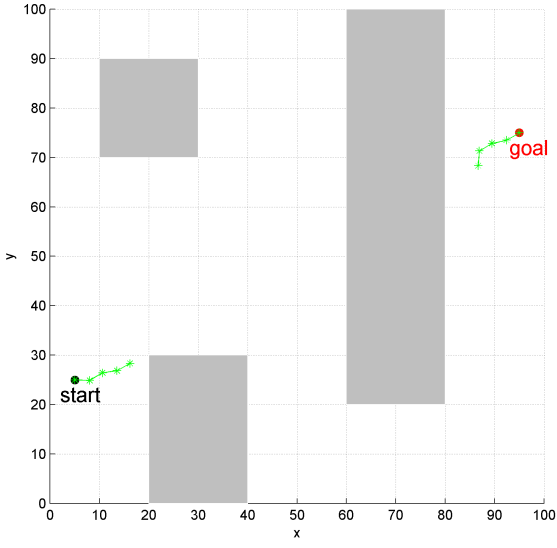


[H. Choset & J. Kuffner, CMU]

Algorithm

Swap trees and repeat, until connection

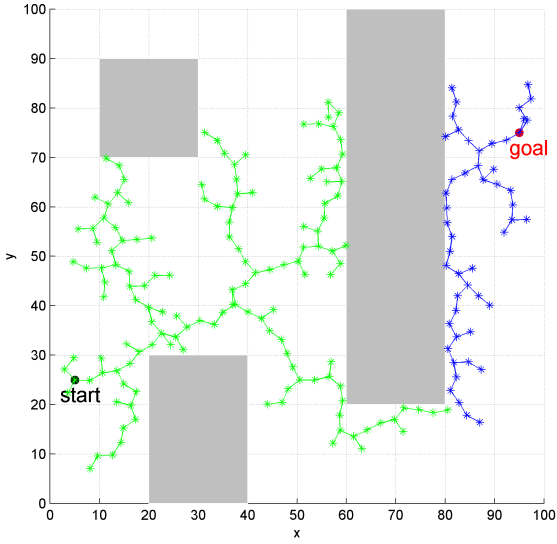
RRT-connect



Algorithm

Expand trees from start and goal until they connect

RRT-connect



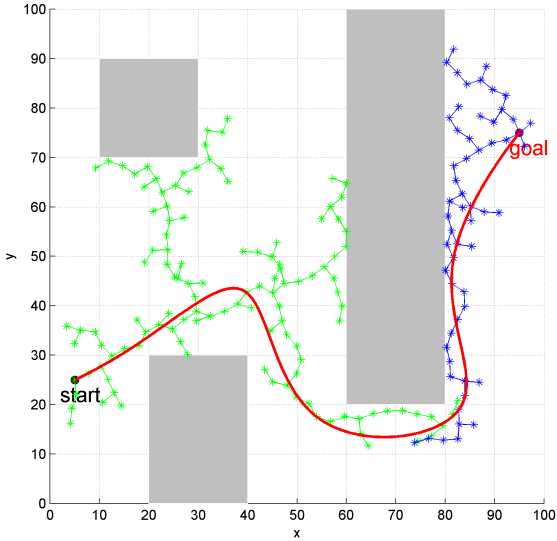
Algorithm

Expand trees from start and goal until they connect

Find path:

- Query from goal to connection
- Query from connection to start

RRT-connect



Algorithm

Expand trees from start and goal until they connect

Find path:

- Query from goal to connection
- Query from connection to start

Downsampling and spline smoothing

Concluding remarks

Probabilistic graph search

- Generation of the graph using random samples and collision check
- Different expansion techniques: PRM, RRT, RRT-Connect
- Path finding relies on deterministic methods
- Many variants and extensions

In any case

- A path is obtained, then generate a trajectory
- Smoothing might be necessary (e.g. splines)
- Handling dynamical constraints can be hard or costly

Selected resources

Books

- S. Lavalle, Planning Algorithms, Cambridge University Press, 2006
- S. Thrun, W. Burgard, D. Fox, Probabilistic Robotics, MIT Press, 2006
- R. Siegwart et al., Introduction to autonomous mobile robots, MIT press, 2011

Open-source libraries

- Open Motion Planning Library (OMPL, in C++)
- Robotics Toolbox by Peter Corke (for Matlab, yet free)
- PythonRobotics
- ROS interfaces: global_planner, MoveIt!