RRT-Connect: An efficient approach to single query path planning

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Authors and Publication Information

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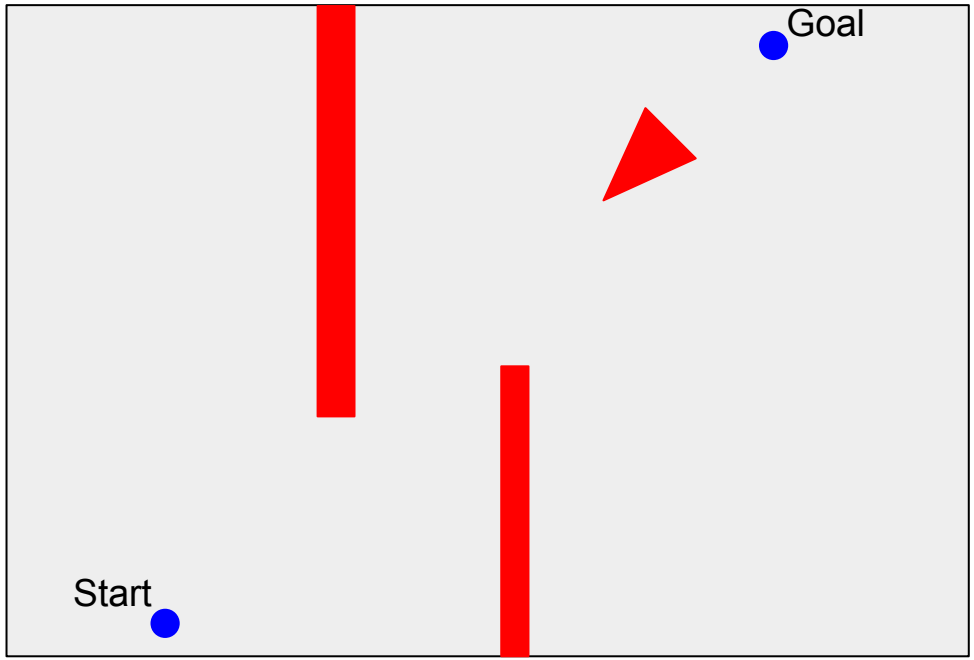
- Presented at IEEE International Conference on Autonomous Robotics (ICRA) in 2000.
- 777 paper citations
- 12 patent citations

Setting up the problem: Path Planning

Given an arbitrary map containing obstacles, how do we determine a path from the start to the goal?



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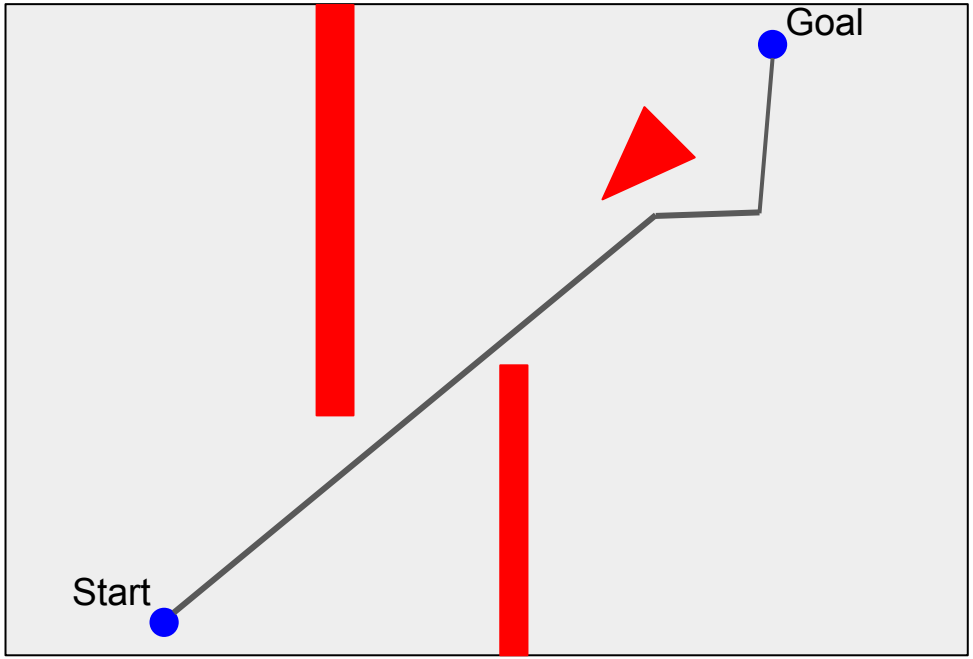

Difficulties of path planning

- Configuration space can have a very high dimension.
- Obstacles can be arbitrarily placed and shaped in the map.
- Final path needs to be feasible for the robot.
- We tend to want paths that optimize values (ex. Minimize distance)

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Two types of path planning

Multi-Query Planning

- We plan to use the same map for several path planning problems.
- Our algorithm should store paths and maybe even ‘explore’ a significant portion of the map.
- Important Algorithm: Probabilistic Roadmap (PRM)

Single-Query Planning

- We only plan to use the same map once (or very infrequently).
- Our algorithm does not need to keep track of currently useless paths; we will throw data away after execution.
- Important Algorithm: Potential Field Method

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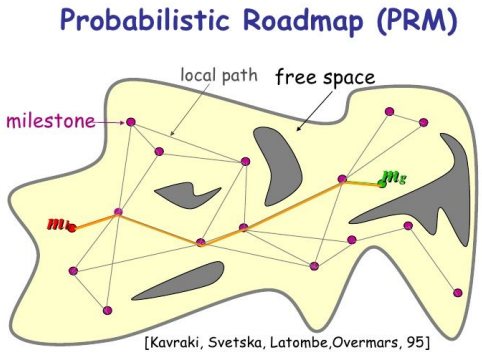
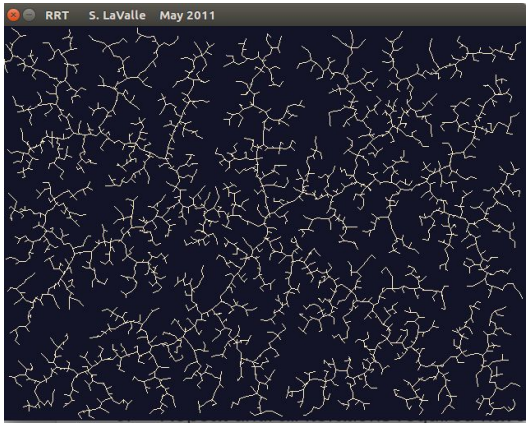
RRT-Connect is a Single-Query Planner

Importance and Impact of Paper

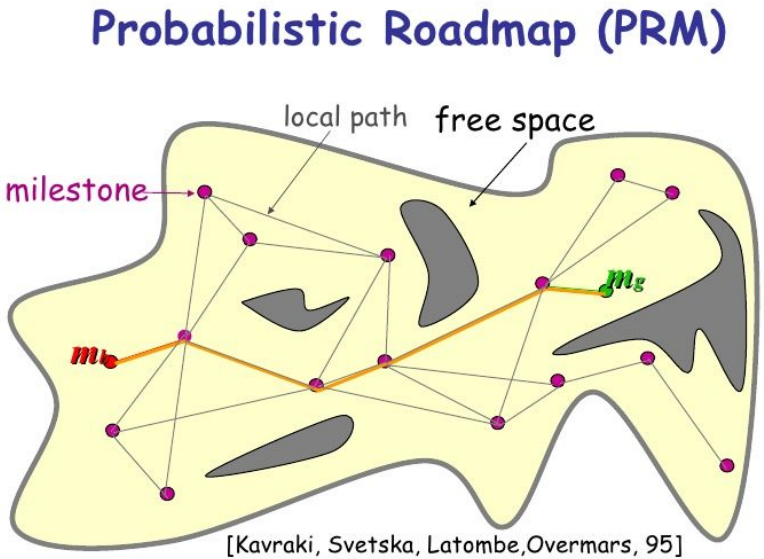
- After the introduction of the probabilistic roadmap method for multi-query planning in 1996 they found widespread use, even in single-query planning.
- The introduction of RRTs (and consequently RRT Connect) provided a single-query based algorithm that provides similar qualities to the PRM.





Probabilistic Roadmap

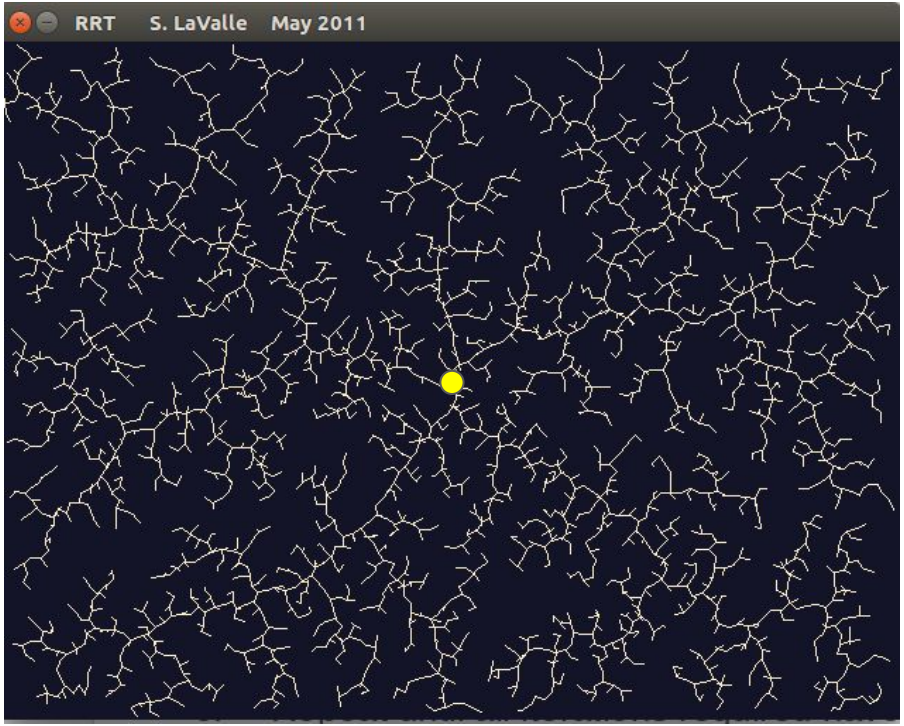
1. Randomly place down a number of vertices into the free space.
2. Use a local planner to connect vertices.
    a. Each vertex tries to connect to k-nearest neighbors.
3. Perform graph search on the created graph to find a path from the start to the goal.



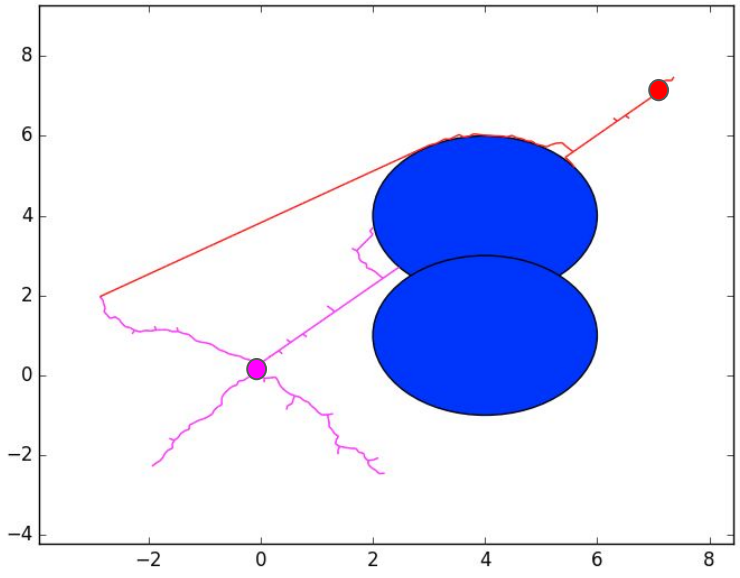
https://www.slideshare.net/ahmad1957/probabilistic-roadmaps-presentation

Rapidly Exploring Random Tree (RRT)

1. Add a vertex at your robot's starting config.
2. Randomly select a point in the free space.
3. Determine nearest neighbor to random node.
4. Add a vertex at least ε units in the direction in the random point from the nearest neighbor.
5. Connect nearest neighbor to new vertex if no collision occurs between them. Otherwise, remove vertex.
6. Repeat until all iterations required have occured.



RRT-Connect



1. Create two RRTs (one at the start and one at the goal).
2. Select a tree and grow it in the normal way.
3. Select the nearest neighbor to the new vertex from the other tree.
4. Build a vertex ε from the nearest neighbor to the new vertex until you reach it or hit an obstacle. (Connect phase)
5. Switch which tree grows and which tree connects. Then repeat

Probabilistic Guarantees

1. If a path exists between two points in a convex, bounded, open, n-dimensional configuration space, then an RRT will find a path connecting them with probability equal to 1 given infinitely many iterations.

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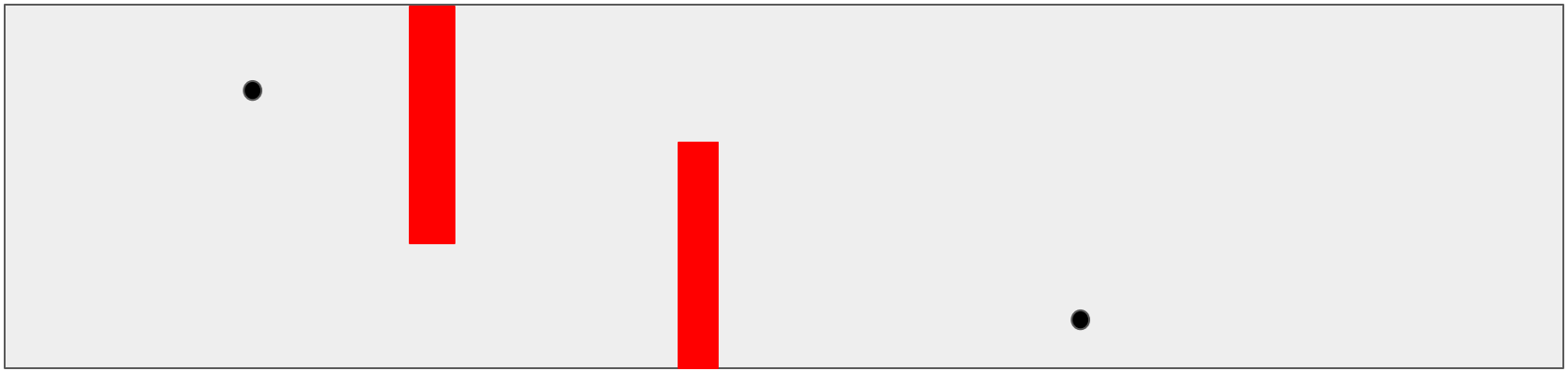

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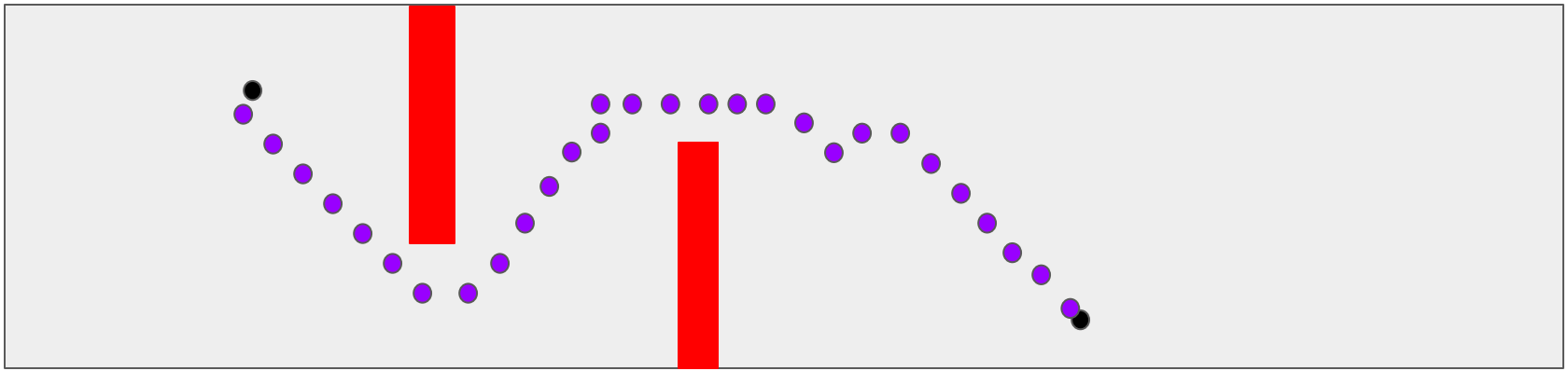

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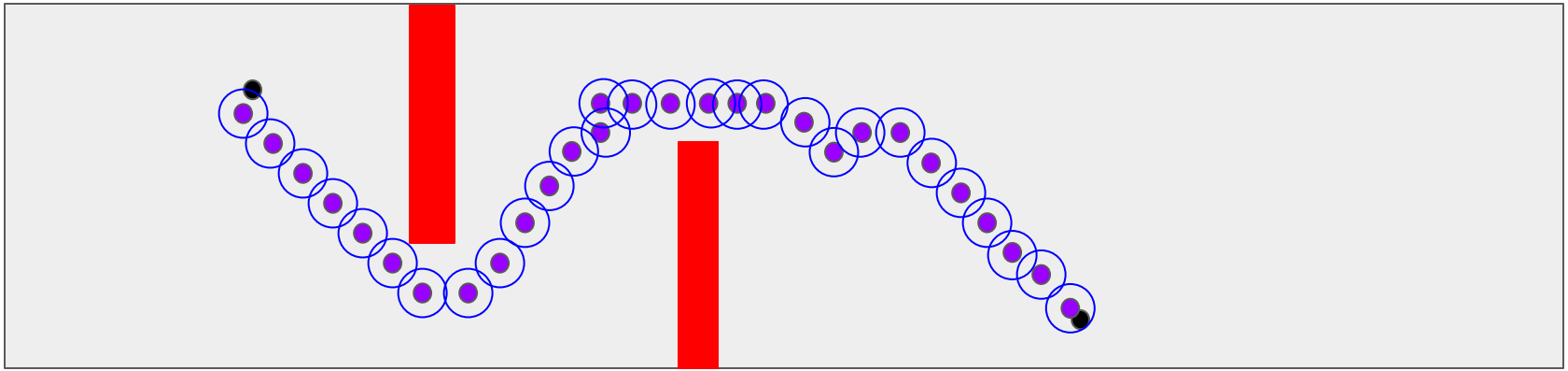


RRT-Connect vs Probabilistic Roadmap

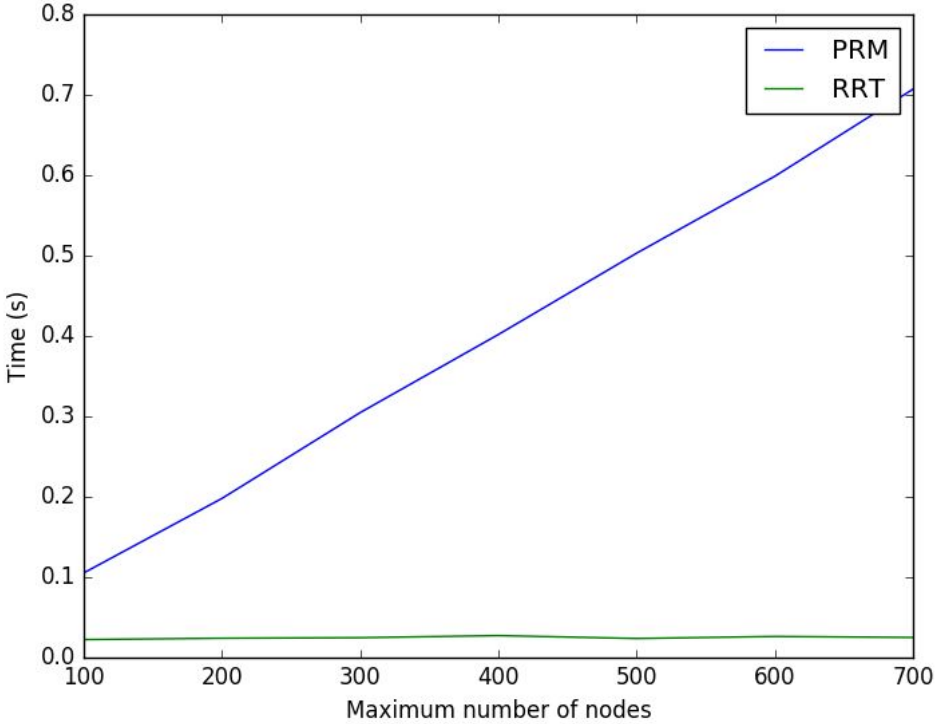
RRT-Connect

- Nearest Neighbor
  - $O(n^2p)$
- Backout Path
  - $O(n)$
- Biased toward goal
  - Encourages connecting to the goal
- Overall more efficient

Probabilistic Roadmap

- K-Nearest Neighbor
  - $O(n^2p + n^2k)$
- Graph Search
  - $O(n^2)$
- Unbiased
  - Connecting to the goal may be difficult

Empirical Evaluation



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1. J. J. Kuffner, S. M. LaValle. RRT-connect: An efficient approach to single query path planning. IEEE International Conference on Robotics and Automation. April 20, 2000. Doi: 10.1109/ROBOT.2000.844730
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