Rapidly-Exploring Random Trees (RRT)

Rapidly-Exploring Random Trees: A New Tool for Path Planning

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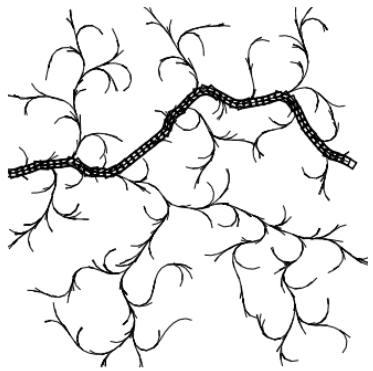
Abstract

We introduce the concept of a Rapidly-exploring Random Tree (RRT) as a randomized data structure that is designed for a broad class of path planning problems. While they share many of the beneficial properties of existing randomized planning techniques, RRTs are specifically designed to handle nonholonomic constraints (including dynamics) and high degrees of freedom. An RRT is iteratively expanded by applying control inputs that drive the system slightly toward randomly-selected points, as opposed to requiring point-to-point convergence, as in the probabilistic roadmap approach. Several desirable properties and a basic implementation of RRTs are discussed. To date, we have successfully applied RRTs to holonomic, nonholonomic, and kinodynamic planning problems of up to twelve degrees of freedom.



1 Introduction

Over the past decade, several randomized approaches have been proposed and successfully applied to the gen-

(a) Technical Report 98-11

(b) S. M. LaValle

Figure: Originally published on Oct. 1998 by S. M. LaValle.

RRT Construction Algorithm

```
GENERATE_RRT(x_init, K, Δt)
1   T.init(x_init);
2   for k = 1 to K do
3       x_rand ← RANDOM_STATE();
4       x_near ← NEAREST_NEIGHBOR(x_rand, T);
5       u ← SELECT_INPUT(x_rand, x_near);
6       x_new ← NEW_STATE(x_near, u, Δt);
7       T.add_vertex(x_new);
8       T.add_edge(x_near, x_new, u);
9   Return T
```

Figure: Source [LaValle, 1998]

Properties

- Relative simplicity;
- Bias toward unexplored space:
  - State selection related to Voronoi region size;
- Probabilistic completeness:
  - Usually insuficient alone; randomness leads to zigzags;
- Input selection:
  - Movement constraints;
  - Metric effects on performance.

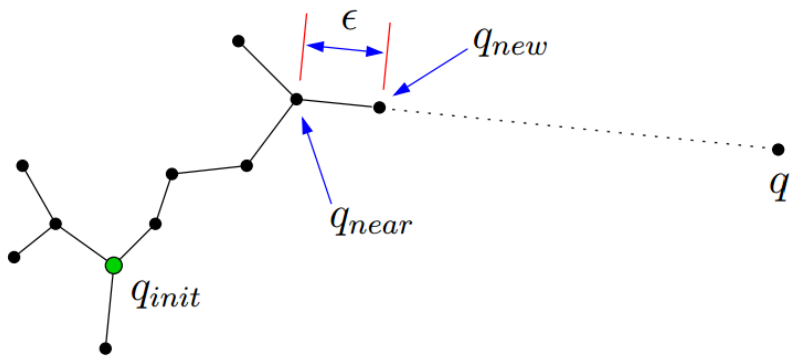


Figure: Source [Kuffner & LaValle, 2000]

Variants

- Nonholonomic constraints on tree growth:
  - Articulated-body;
  - Rigid-body.
  - Steering;
- Obstacles:
  - Selection of random free states;
  - Transition validity for new states.
- Bias toward goal:
  - Avoids "bad luck";
  - Needs to be slight.
- BiRRT, RRT*, DO-RRT, BI^{2}RRT*, I-RRT-C ...

References

S. M. Lavalle, *Rapidly-Exploring Random Trees: A New Tool for Path Planning*, 1998, [Online]. Available: http://msl.cs.uiuc.edu/~lavalle/papers/Lav98c.pdf

J. J. Kuffner and S. M. LaValle, "RRT-Connect: An Efficient Approach to Single-Query Path Planning," *Proceedings IEEE International Conference on Robotics and Automation*, pp 995–1001, 2000.