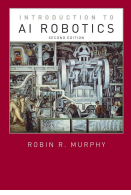
14d Specific Learning Objectives

- Describe the piano mover's problem and why it is different than route planning.
- Explain the similarities and differences between rapidly exploring random tree (RRT) and A* types of algorithms.
- List the criteria for evaluating a path planner, and, if given a description of a path or motion planner, use the criteria to rate the planner's utility

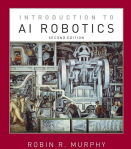
14.6 Motion Planning
14.7 Criteria for Evaluating Path and Motion Planning



14d Motion Planning Problem

- Motion planning stems from industrial manipulator branch of robotics where the pose of robot (or part a robot carries) cannot be abstracted away
  - Moving an arm through an opening and then lift it up and around obstacles in order to assemble a part
- **Pose is critical**: Has to flip the piano, so can't reduce the configuration space to 3DOF
  - Motion planning problem is often called piano mover problem

http://billingsgazette.com/news/local/it-makes-people-happy-blind-piano-mover-technician-finds-his/article_0ac7418d-e1b1-5523-b63c-7cbd31abaca0.html



General Idea

- No longer just waypoints but poses as well- plus whether it is possible to change and move from one (waypoint, pose) to another (waypoint, pose)
- Start with an a priori map
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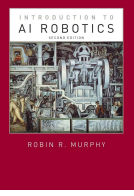
- Approaches
  - Sampling methods dominate
    - Rapidly-exploring Random Tree (RRT)



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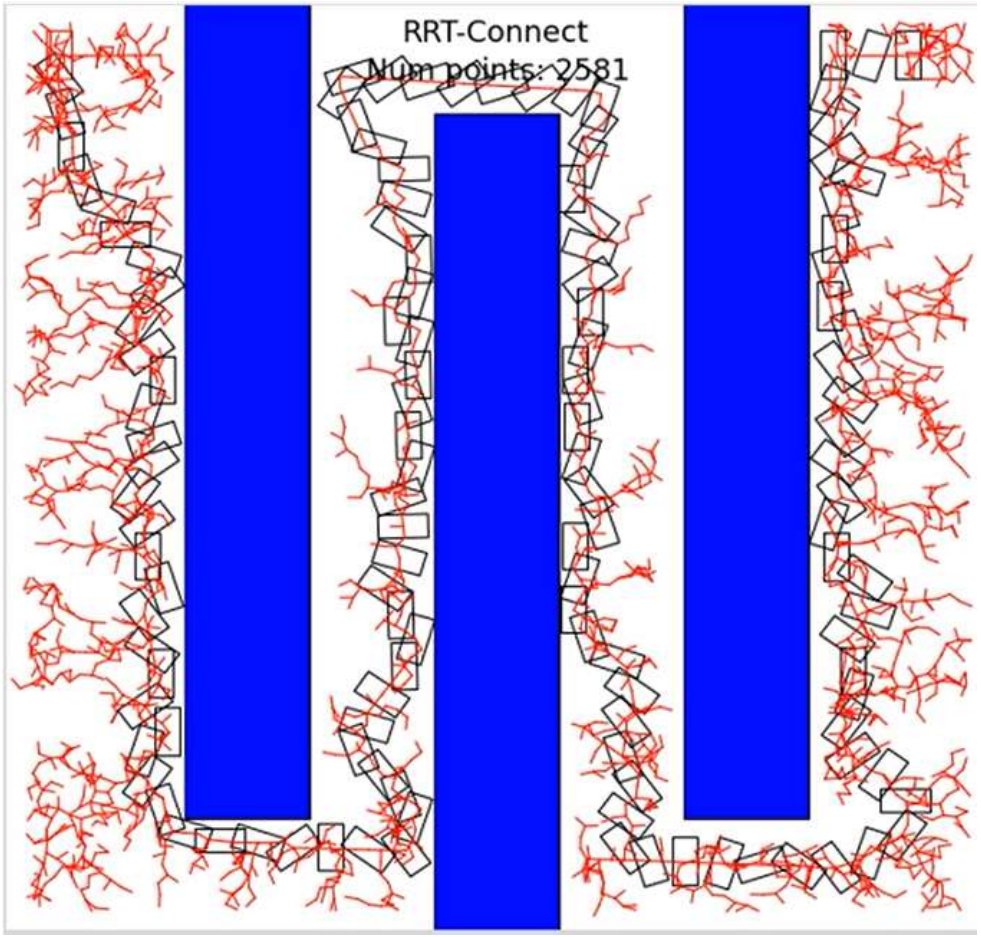
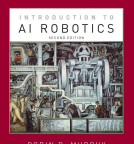
RRT-Connect



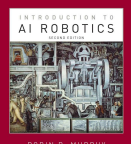
A random tree generated by the RRT-Connect algorithm and a partial path through the tree.

Check out https://www.youtube.com/watch?v=rPgZyq15Z-Q



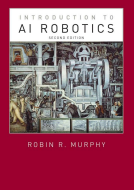
14d RRT-Connect Algorithm (1)

- Start with an a priori map and a starting node (location, pose) which serves as the root of the tree.
- Randomly sample the space and generate a list of candidate (location, pose) nodes.
- Randomly pick a candidate node from the list and check to see if the node contains a valid pose where the robot or part is not inside a wall or object.
  - If the node is not valid, repeat until you find a valid node.
  - Note that the methods only check to see if the randomly selected (location, pose) is valid, they do not search for all valid poses at the location



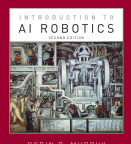
14d RRT-Connect Algorithm (2)

- For the valid candidate node, check to see if there is a collision-free path between the nearest vertex in the tree and the node,
  - that is, can the robot physically translate and rotate from the vertex in the tree to the candidate node without hitting anything.
- If so, add the node to the tree. If not, discard the candidate node and pick another.
- Continue until the tree includes the goal.
- Once the tree is built, then plan a path through the tree



14d Criteria for Evaluating Path Planners

- Complexity
- Sufficiently represents the terrain
- Sufficiently represents the physical limitations of the robot platform
- Compatible with the reactive layer
- Supports corrections to the map and re-planning



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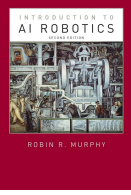
Summary

- Motion planning connotes path planning (search) for a destination where the workspace is known a priori but the configuration space (knowledge representation) is difficult to simplify, often because the pose of the robot cannot be ignored
- Motion planning attempts to solve the piano movers problem
- One popular class of search algorithms is RRT, which samples the space to build a tree that meets the constraints



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References of RRTs

1. S. M. LaValle. *Rapidly-exploring random trees: A new tool for path planning*. TR 98-11, Computer Science Dept., Iowa State Univ. <http://janowiec.cs.iastate.edu/papers/rrt.ps>, Oct. 1998
2. S. M. LaValle and J. J. Kuffner. *Randomized kinodynamic planning*. In Proc. IEEE Int'l Conf. on Robotics and Automation, 1999
3. James J. Kuffner, Jr, Steven. M. LaValle. *RRT-Connect: An Efficient Approach to Single-Query Path Planning*. In Proc. 2000 IEEE Int'l Conf. on Robotics and Automation (ICRA 2000)