CS 369: Introduction to Robotics

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HAVERFORD
COLLEGE

Outline for today

- Sampling-based motion planning

- Robot perception

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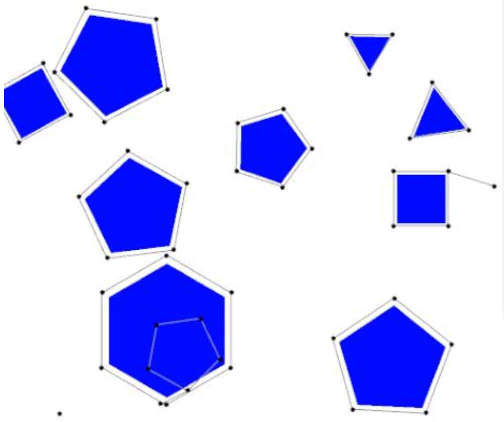
Motion planning algorithms

	Graph search	Sampling-based
Completeness	Complete	Probabilistically complete
Path optimality	Optimal	Depends
Memory usage	High (store entire map)	Low (store sampled nodes)
Best for	Low-dimensional, 2D grids	High-dimensional, complex spaces

Probabilistic roadmap (PRM)



- Consists of two phases: construction and query
- Construction:
  - Take random samples from the robot's configuration space
  - Connect configurations to neighbors while avoiding collisions with obstacles
  - Add configurations and connections until the roadmap is dense enough
- Query:
  - Connect start and goal configurations to the graph
  - Obtain path with a graph search algorithm

Wikipedia

Rapidly exploring random tree (RRT)

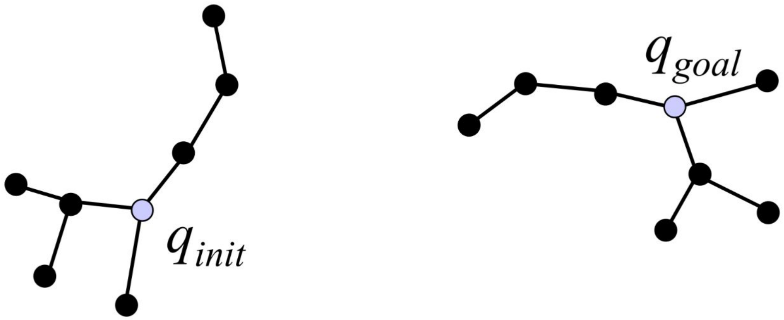
Grows a tree rooted at the start configuration by using random samples.

Algorithm BuildRRT
    Input: Initial configuration q_{init}, number of vertices in RRT K, incremental distance Δq
    Output: RRT tree T

    T.init(q_{init})
    for k = 1 **to** K **do**
        $q_{rand} \leftarrow$ RAND_CONF()
        $q_{near} \leftarrow$ NEAREST_VERTEX(q_{rand}, T)
        $q_{new} \leftarrow$ NEW_CONF(q_{near}, q_{rand}, Δq)
        T.add_vertex(q_{new})   // Only add if connection is feasible
        T.add_edge(q_{near}, q_{new})
    return T

Wikipedia

RRT-Connect



Grows two RRTs towards each other.

RRT_CONNECT(q_{init}, q_{goal})
　T_a.init(q_{init}); T_b.init(q_{goal})
　for k = 1 **to** K **do**
　　q_{rand} = RANDOM_CONFIG()
　　if not (EXTEND(T_a, q_{rand}) = Trapped) **then**
　　　if (EXTEND(T_b, q_{new}) = Reached) **then**
　　　　return PATH(T_a, T_b)
　　SWAP(T_a, T_b)　// Instead of switching, use T_a as smaller tree
　return Failure

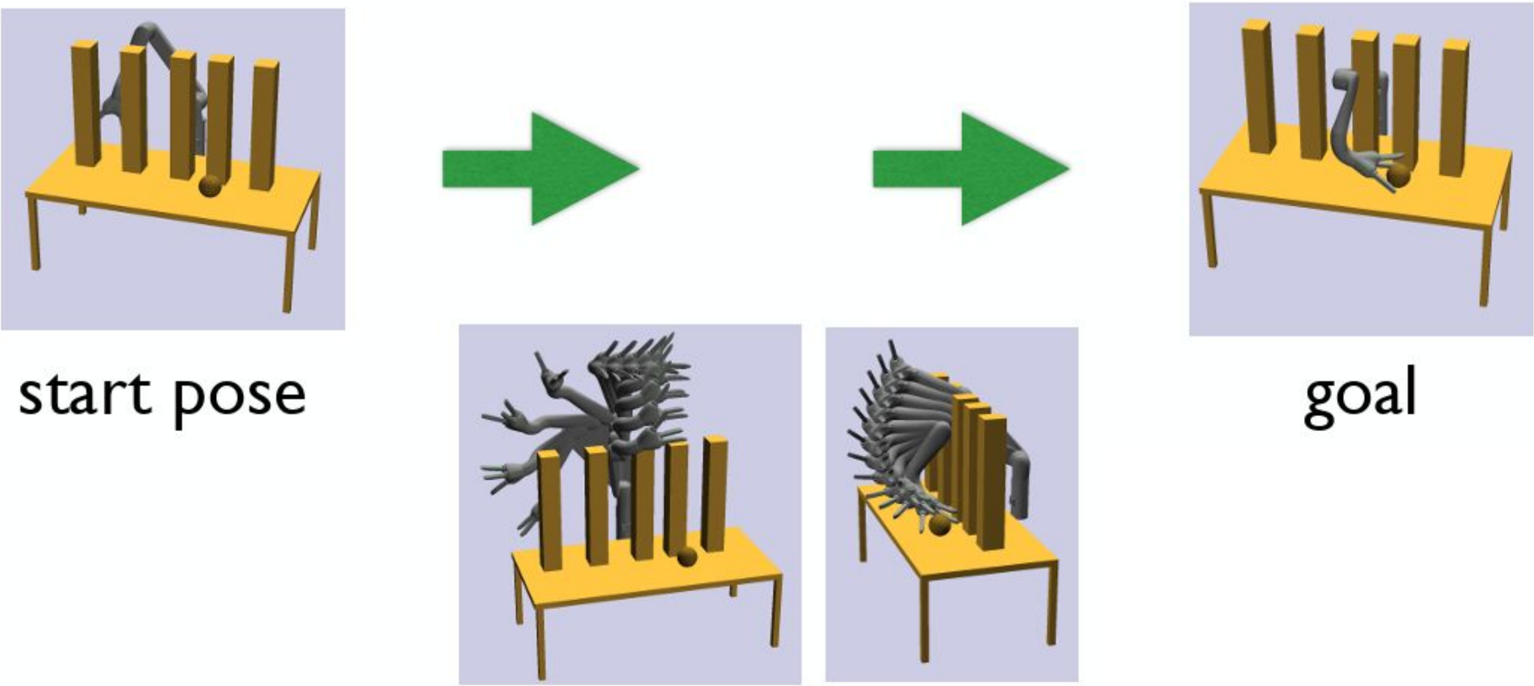
RRT*

- RRT with two improvements:
  - **Best neighbor search:** when adding a new node, RRT* checks nearby nodes in the tree to connect to the one that results in the lowest cost from the root, rather than just the single nearest node
  - **Tree rewiring:** after adding a new node, the algorithm checks if neighboring nodes can have their path cost reduced by switching their parent to the newly added node
- Computationally more expensive, asymptotically optimal

RRT* pseudo code

T.init(q_{init})
for $i = 0$ **to** max_iter:
    q_{rand} = RAND_CONF()
    if OBS(q_{rand}) == True, try again
    q_{near} = NEAREST(q_{rand}, T)
    if not EXTEND(q_{near}, q_{rand}) == Trapped:
        UPDATE(q_{rand}, q_{near})
    q_{best}, $neighbors$ = FIND_NEIGHBORS(T, q_{rand}, rad)
    if q_{best} != q_{near} and **not** EXTEND(q_{best}, q_{rand}) == Trapped:
        UPDATE(q_{rand}, q_{best})
    for n in $neighbors$:
        if COST(q_{rand}) + DIST(q_{rand}, n) < COST(n) **and** not EXTEND(q_{rand}, n) ==
Trapped:
            UPDATE(n, q_{rand})
return T

Putting it all together



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