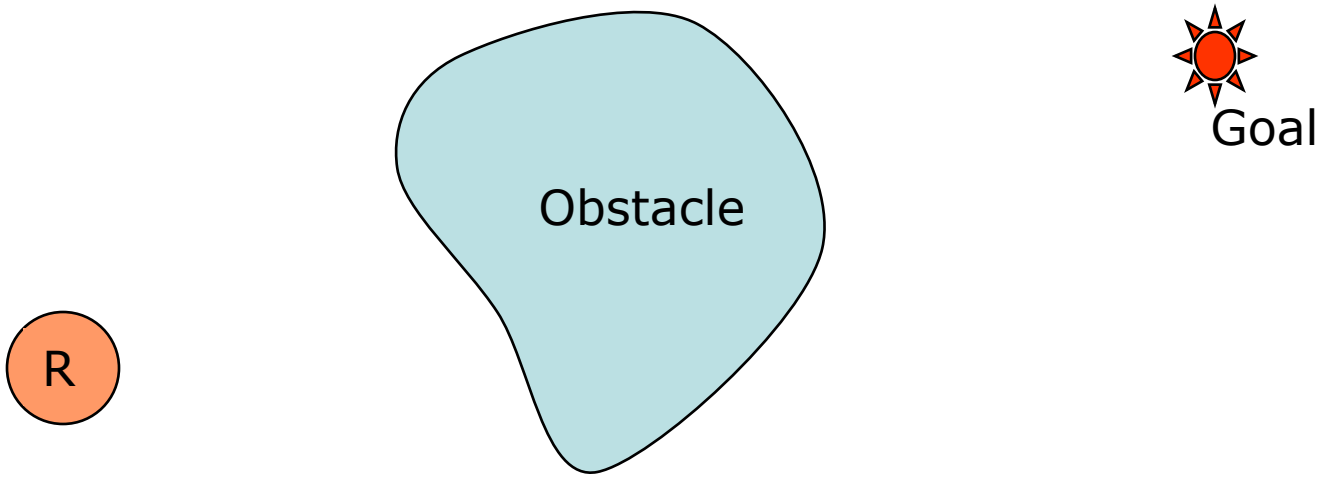
Motion Planning (3/3)

Instructor
Prof. Shih-Chung Kang

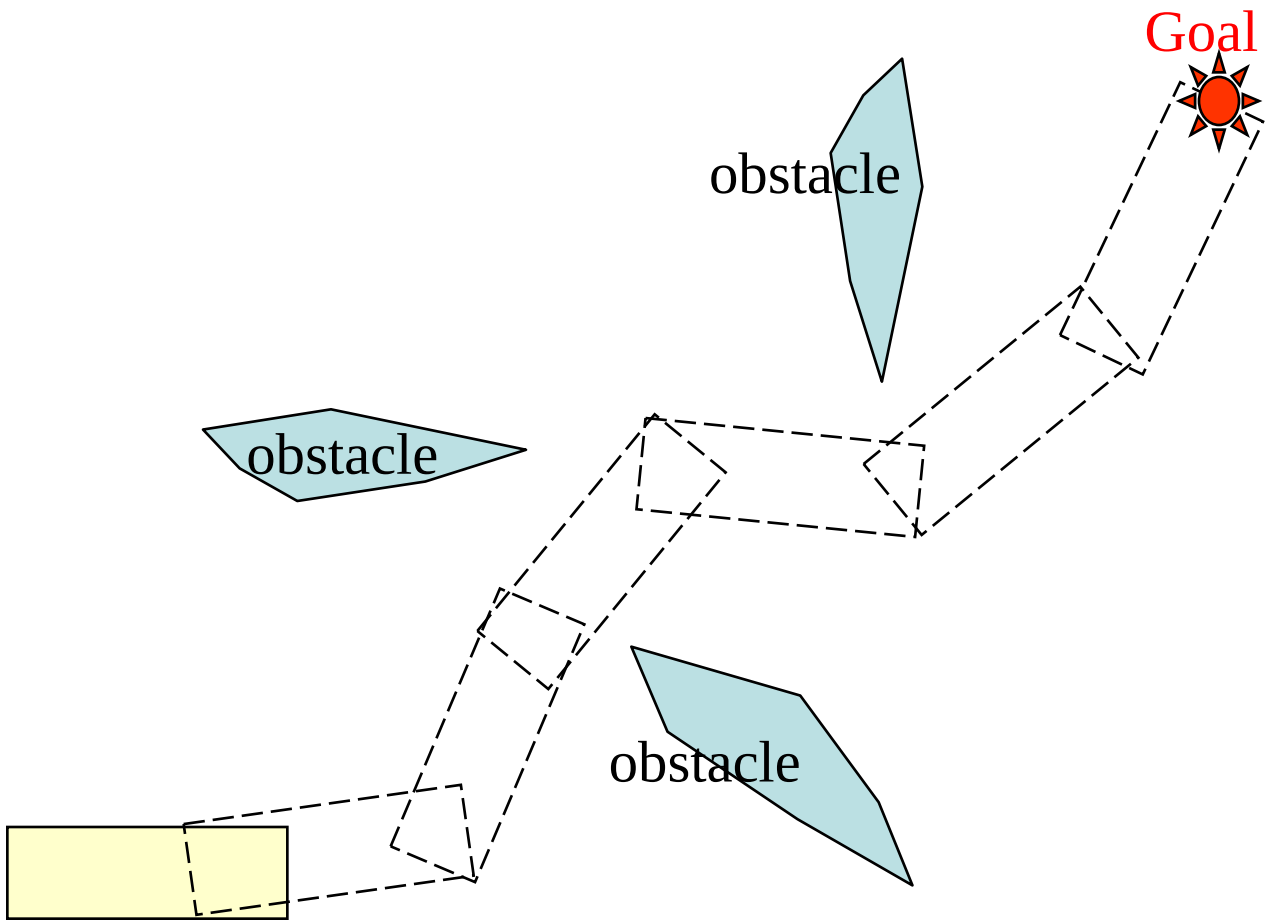
2008 Spring

The motion planning problem

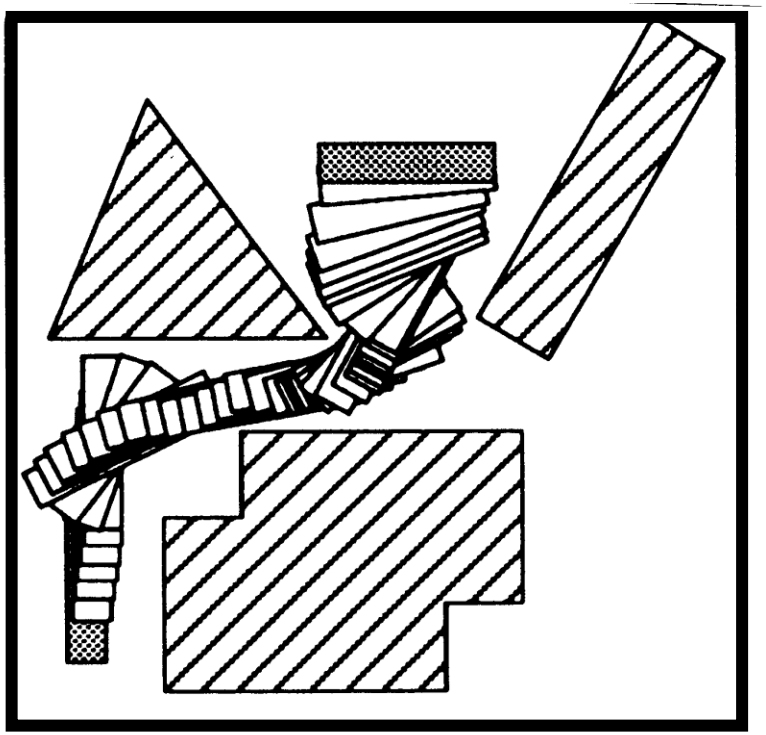


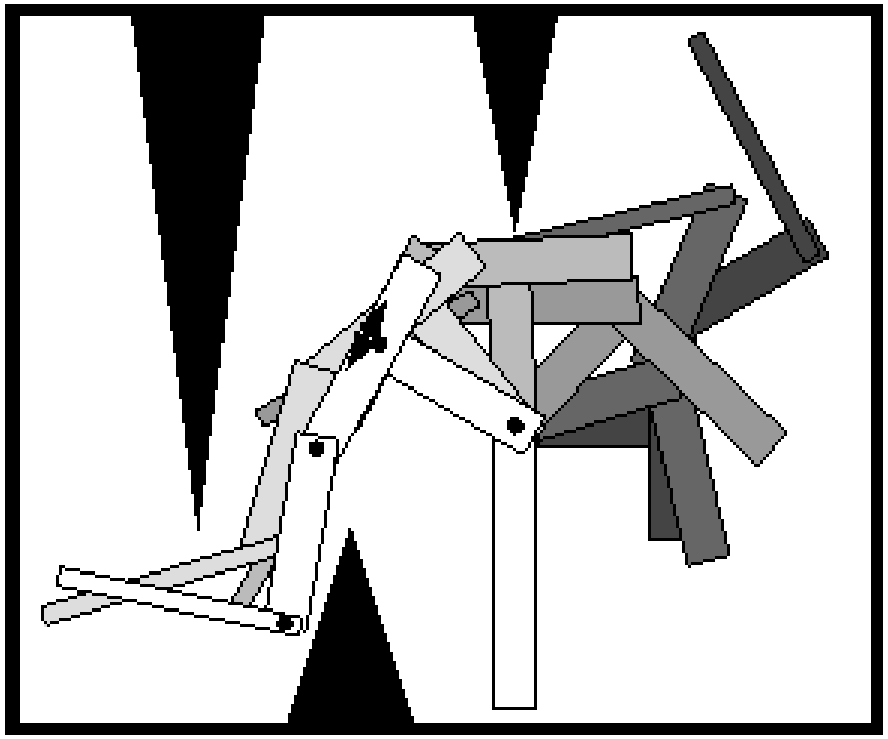
(I) Configuration Space

What is a Path?



What is a Path?

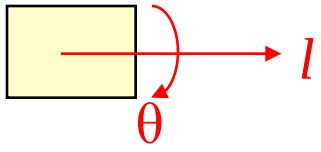


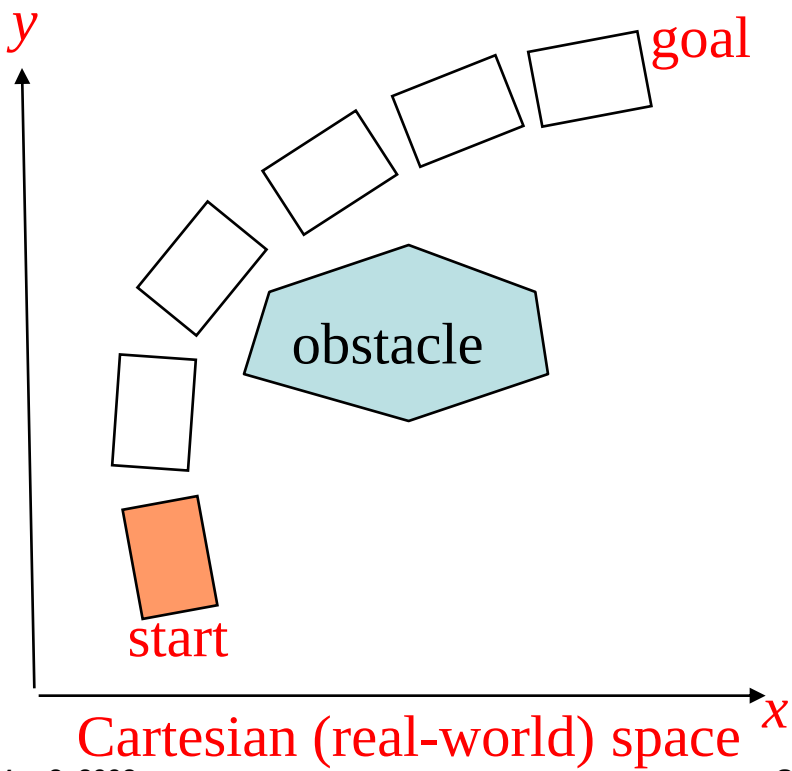


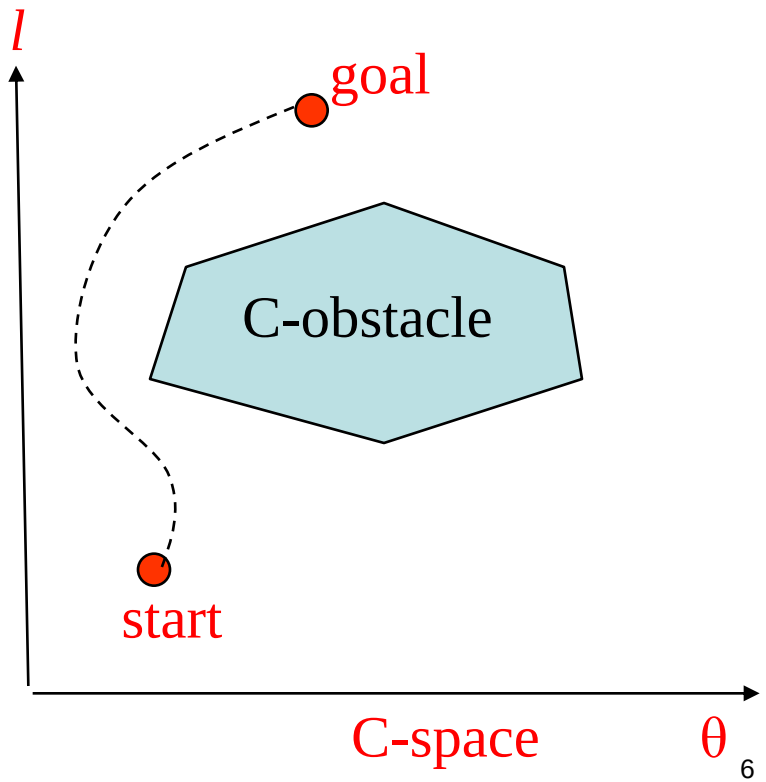
How to simplify this problem?

Use C-space

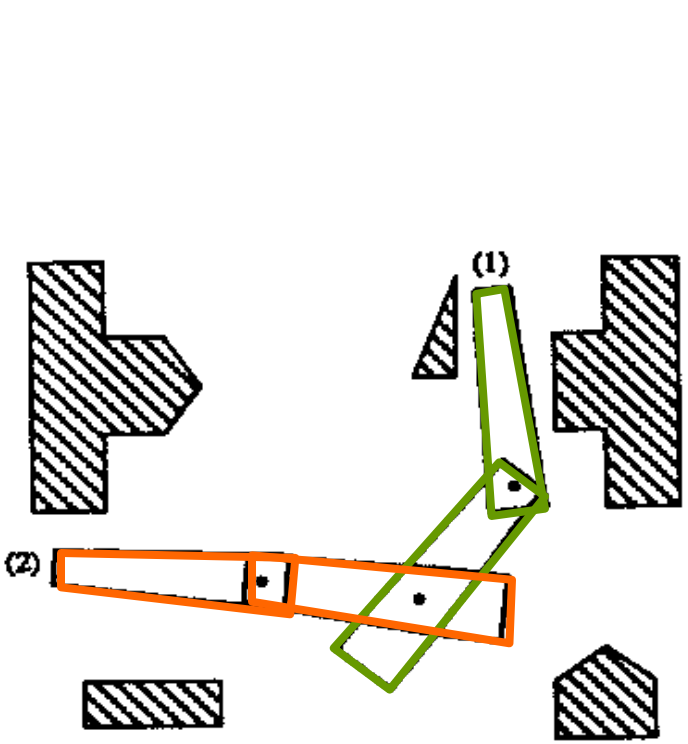
Tool: Configuration Space (C-Space C)

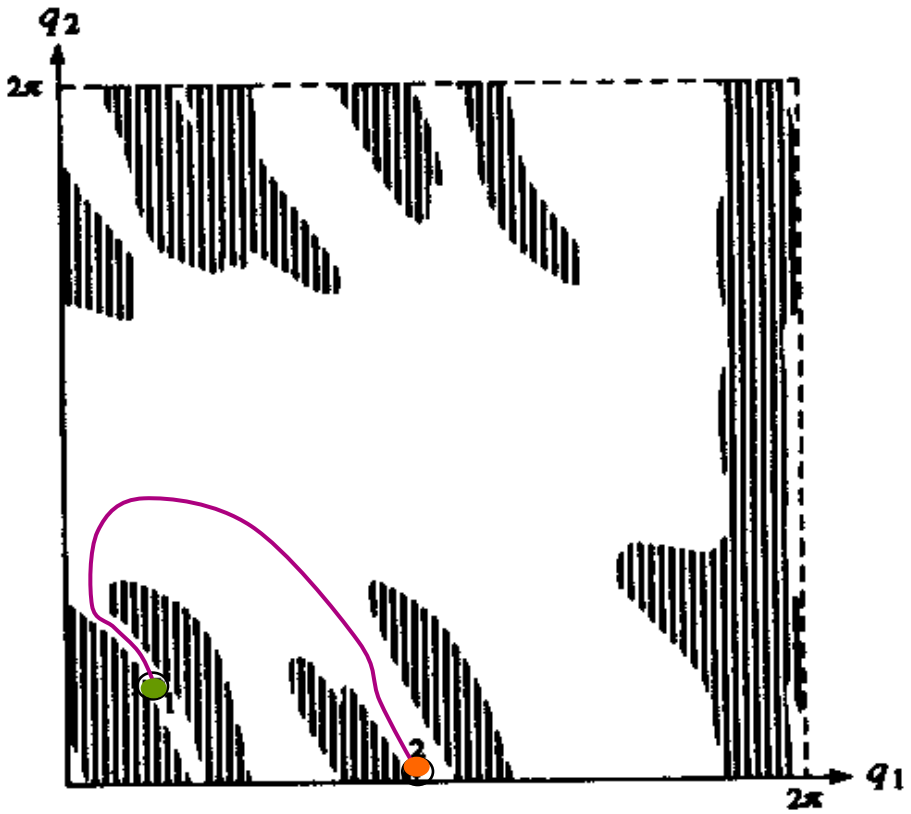




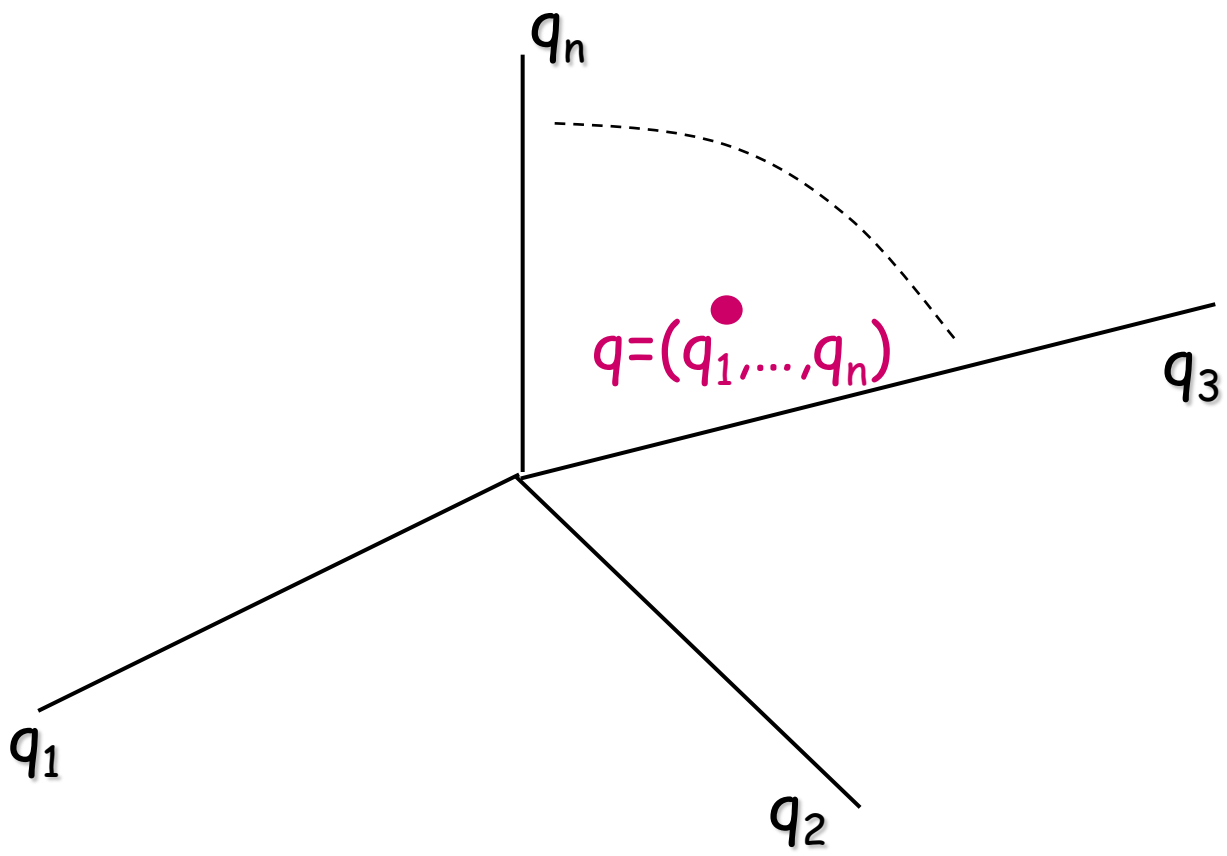


Tool: Configuration Space(C-Space C)





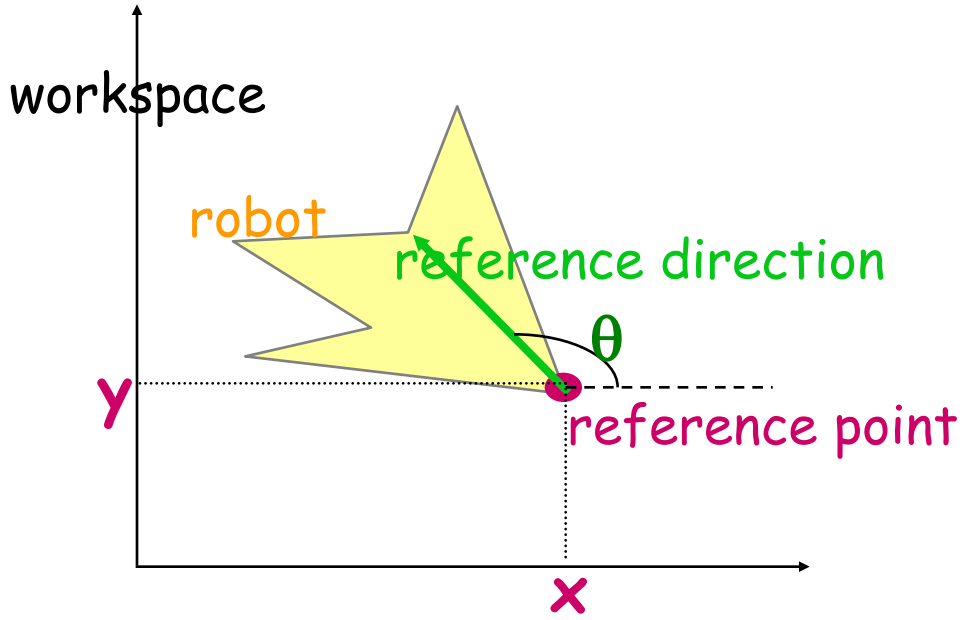
Configuration Space (C-space)



Definition

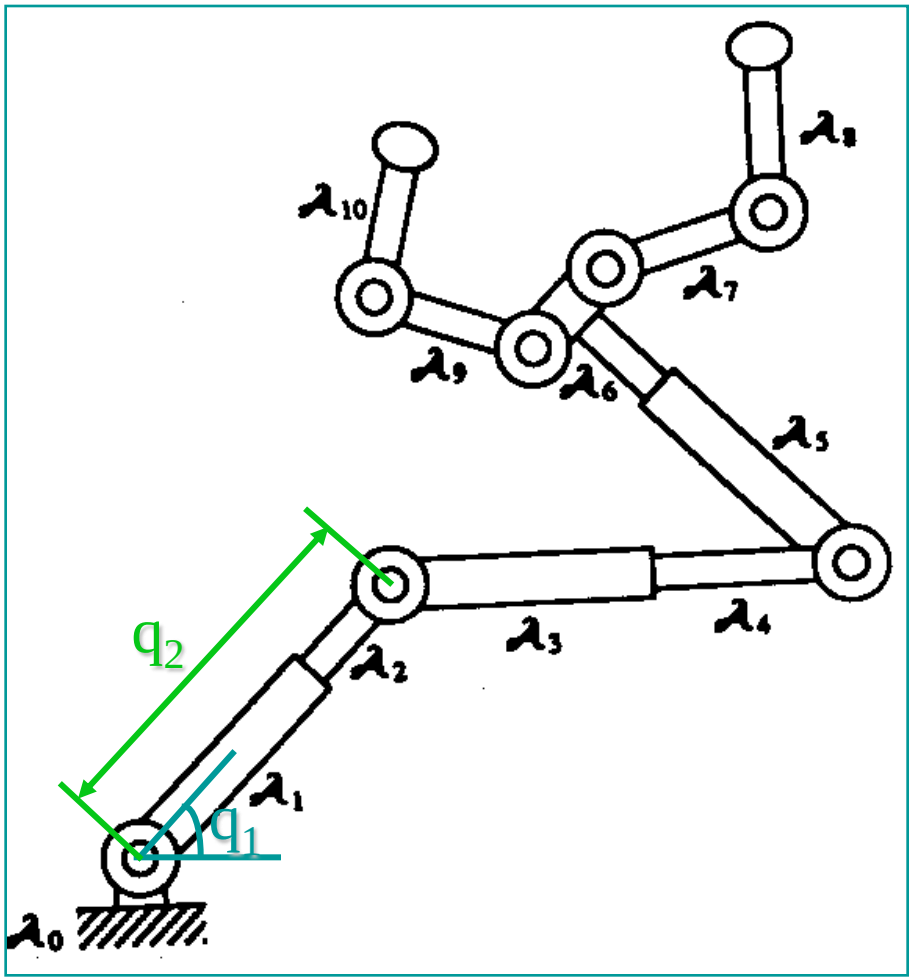
- A robot configuration is a specification of the positions of all robot points relative to a fixed coordinate system
- Usually a configuration is expressed as a “vector” of position/orientation parameters

Rigid Robot Example



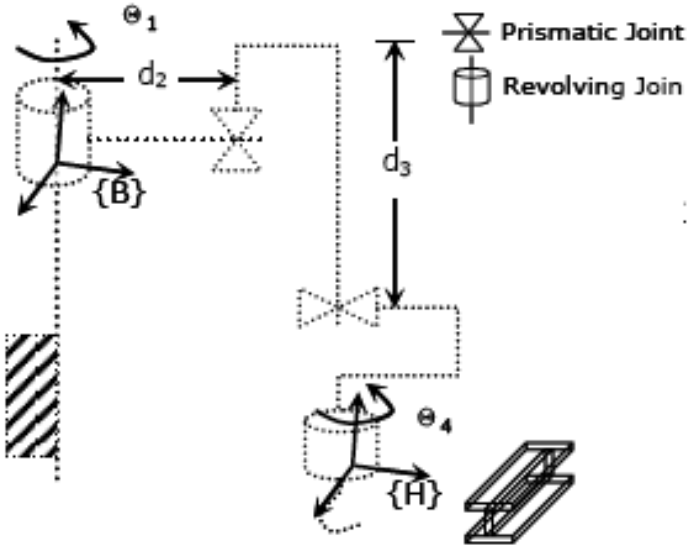
- 3-parameter representation: $q = (x,y,\theta)$
- In a 3-D workspace q would be of the form $(x,y,z,\alpha,\beta,\gamma)$

Articulated robot example

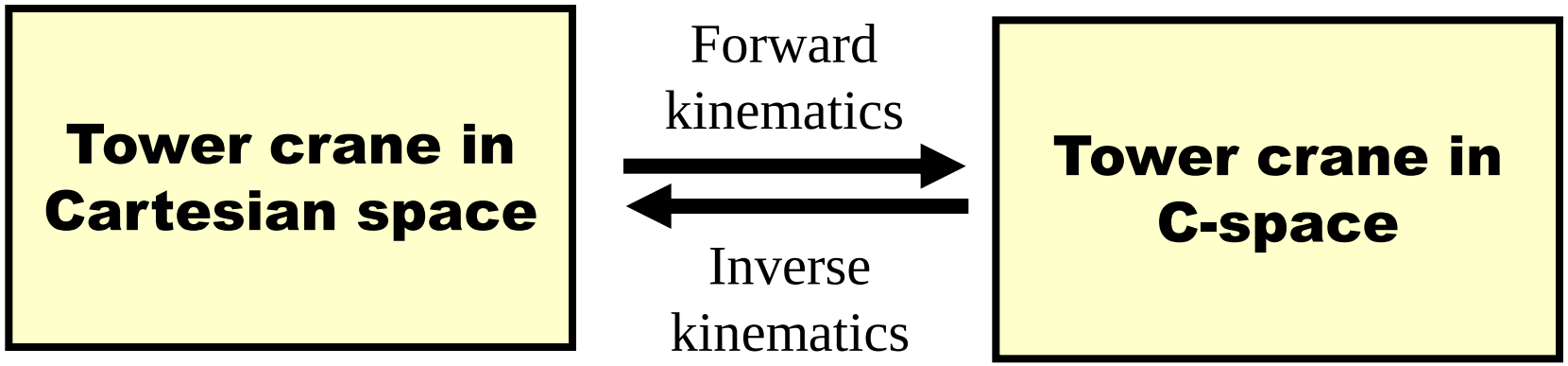


$q = (q_1, q_2, \ldots, q_{10})$

Find the C-space of a tower crane



Using C-space to simplify the motion planning of a tower crane



The geometrical information to describe a tower crane

Four parameters: θ1, d2, d3, and θ4

Using C-space to simplify the motion planning of a tower crane

Tower crane in Cartesian space

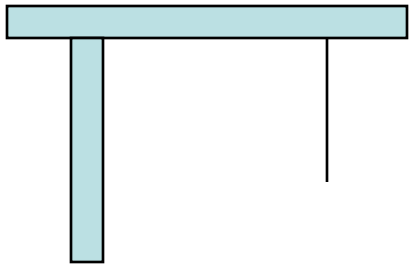
Forward kinematics

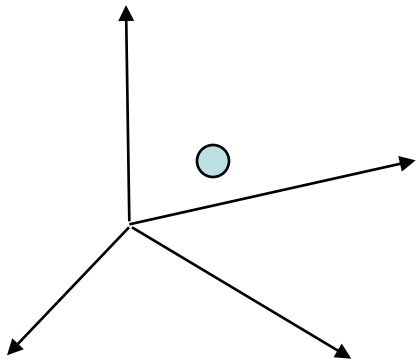
Inverse kinematics

Tower crane in C-space

The attitude of the tower crane

Can be represented by a point in C-space





The benefit from using C-space (1/2)

- In C-space, we are able to describe the crane geometry in space using the minimal set of parameters.
- For example, the position in space (the attitude) of a tower crane in Cartesian space can be described by only four variables, θ1, d2, d3, and θ4.
- Because C-space is constructed by the four space factors, a set of the four variables is a point in C-space.
- A motion of a tower crane can be described by a series of these four variables, which can form a continuous line in C-space.

The benefits from using C-space (2/2)

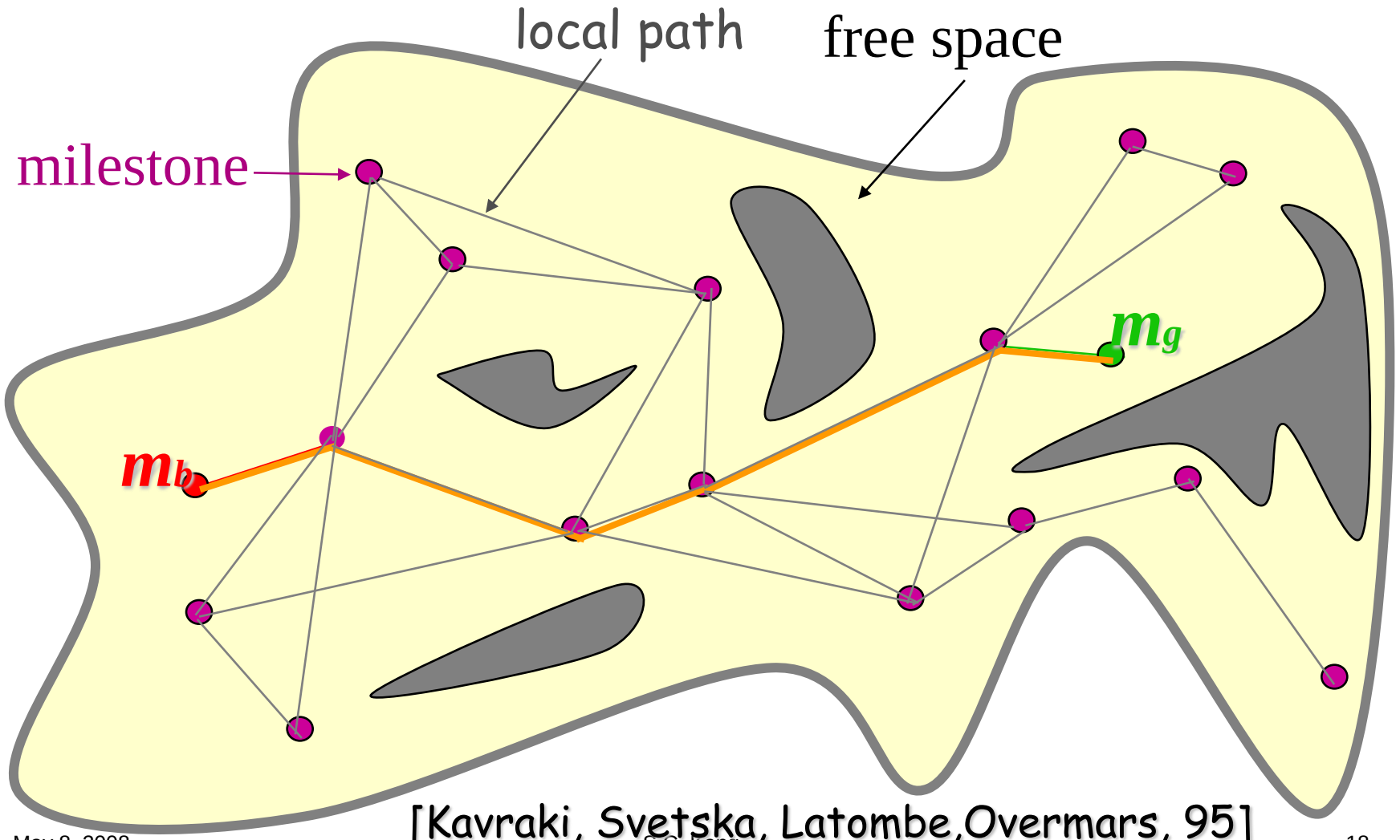
- After the direct and inverse kinematics of manipulators are derived, we can transfer the crane model and obstacles from the Cartesian space to a C-space.
- The problem of finding a collision-free erection path on a complex construction site can be simplified by finding a path that does not go into C-obstacle regions in the C-space.
- Because this method does not need to deal with the full geometry and kinematics information of the whole crane in the Cartesian space, the computation and complexity of the path planning problem is significantly reduced.

(II) Motion planning

PRM and RRTs method

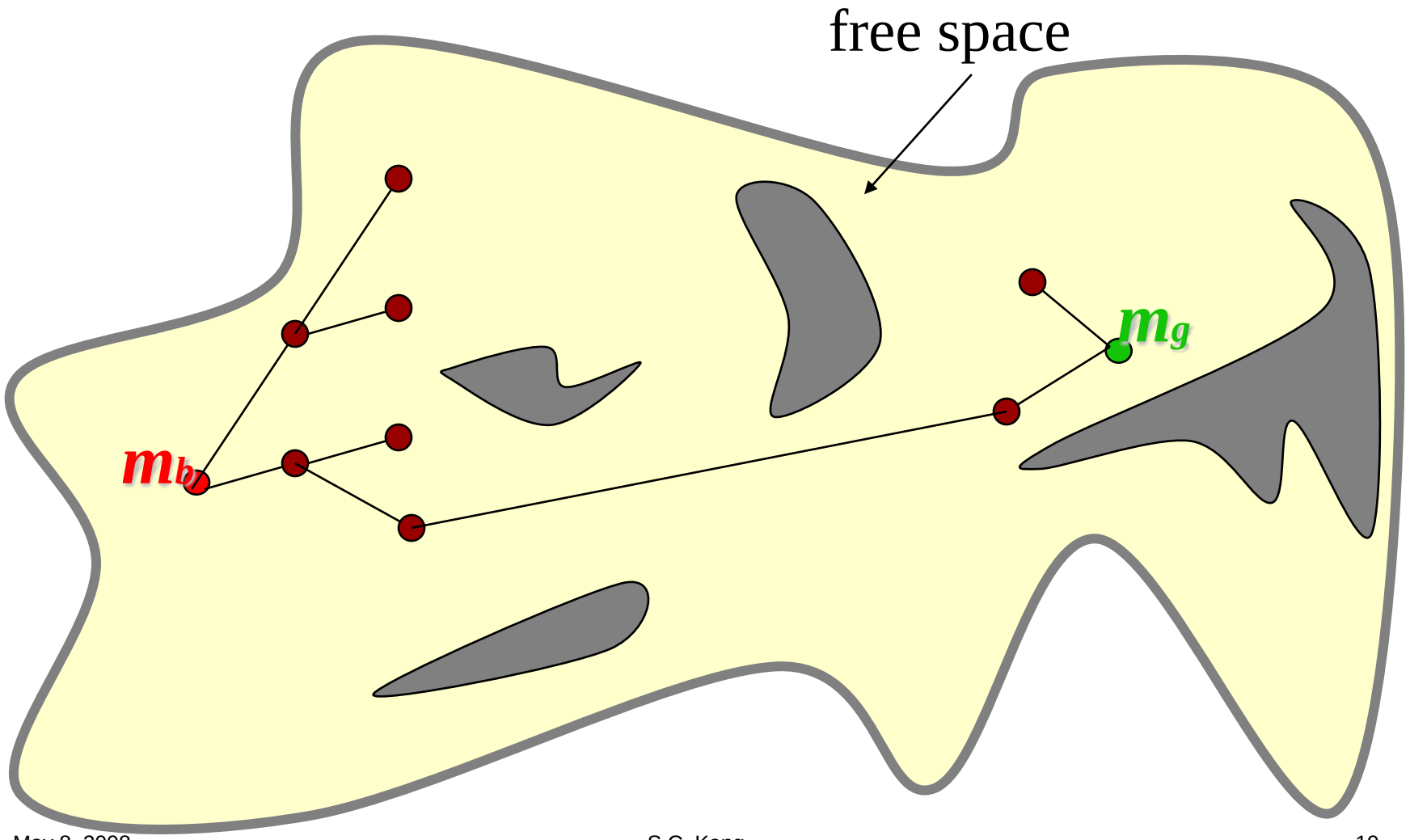
A tower crane example

Probabilistic Roadmap (PRM)



[Kavraki, Svetska, Latombe,Overmars, 95]

Rapidly-exploring Random Trees (RRTs)



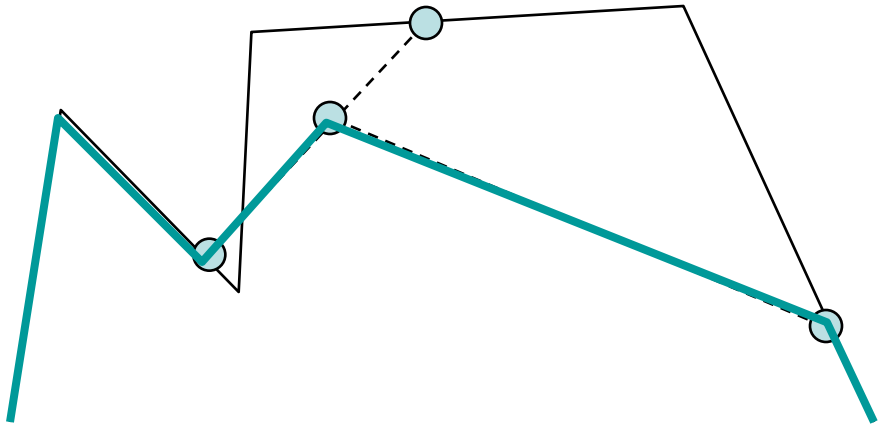
Weaker Completeness

- Complete planner → Too slow
- Heuristic planner → Too unreliable

- **Probabilistic completeness**:
  If there is a solution path, the probability that the planner will find is a (fast growing) function that goes to 1 as running time increases.

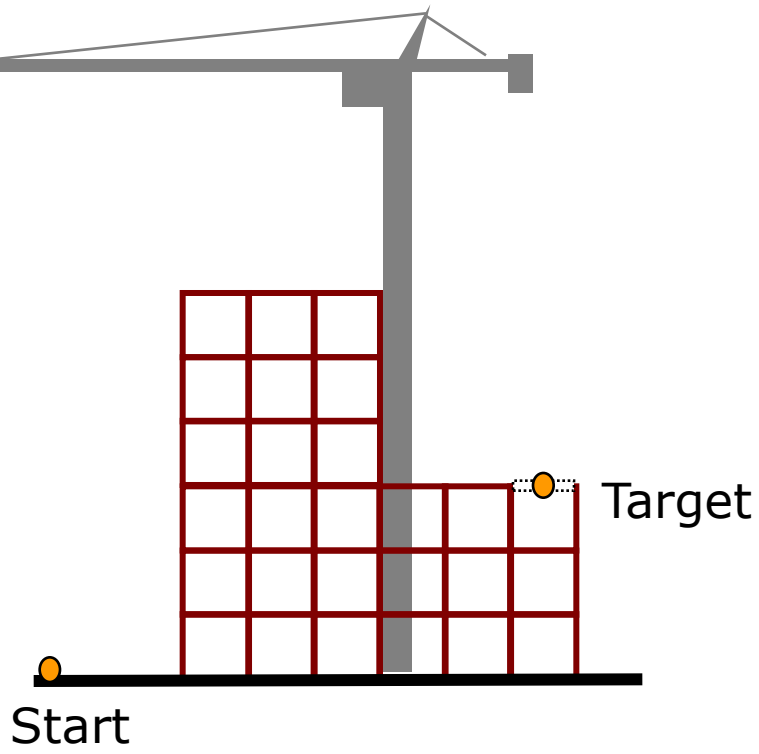
Issues

- Why random sampling?
  -convenient incremental scheme
- Smart sampling strategies
  -sample the points which have higher probability to be chosen in the final path.
- Final path smoothing



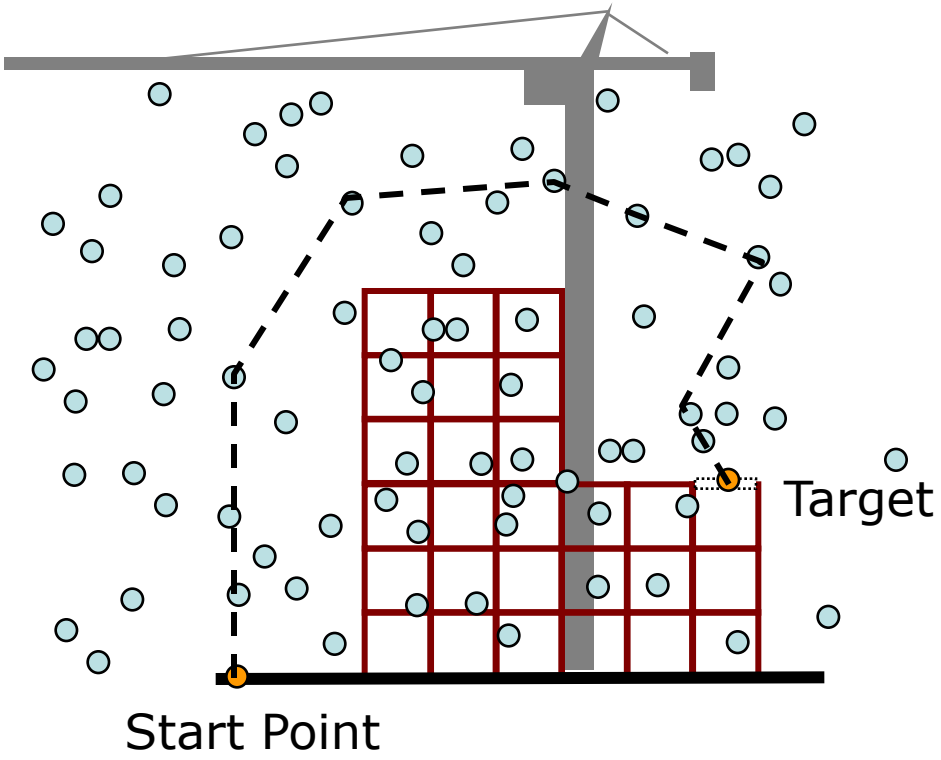
How to find an erection path?

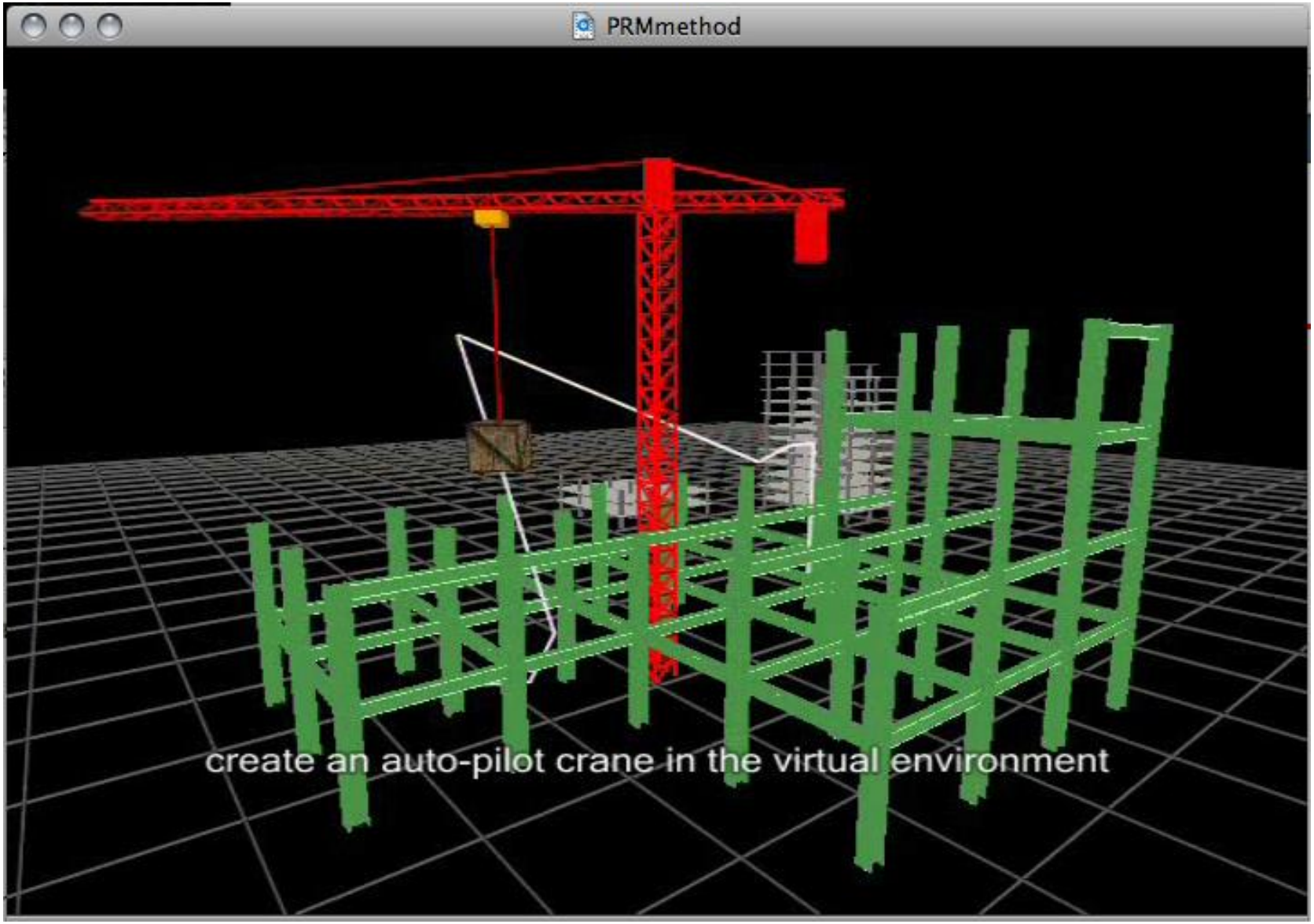
- The path needs to be collision-free
- Also needs to reachable by the crane



How to find an erection path?

- Using Probabilistic Roadmap approach (PRM) (Latombe, 1985)
  - Sample points within crane's reachable area
  - Link the points to find a collision-free path



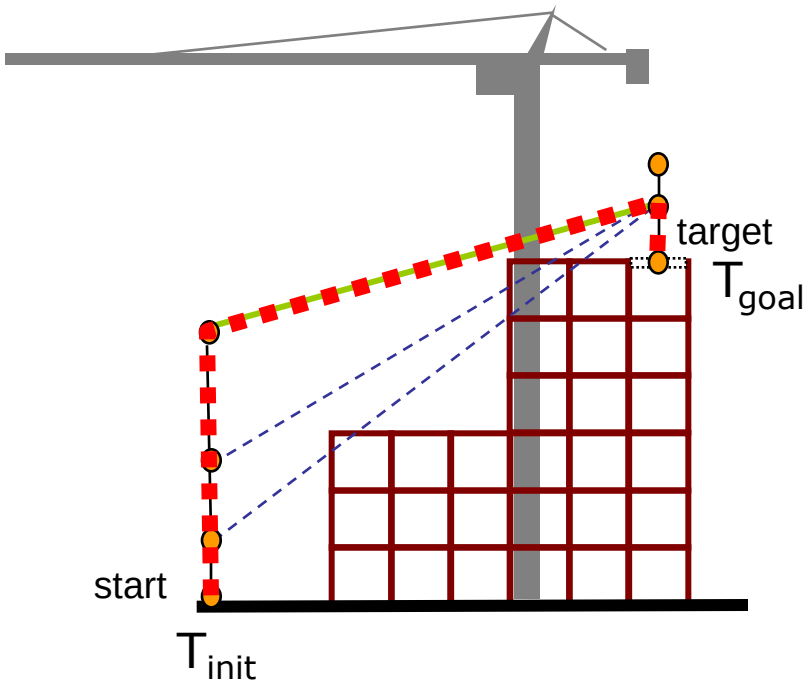


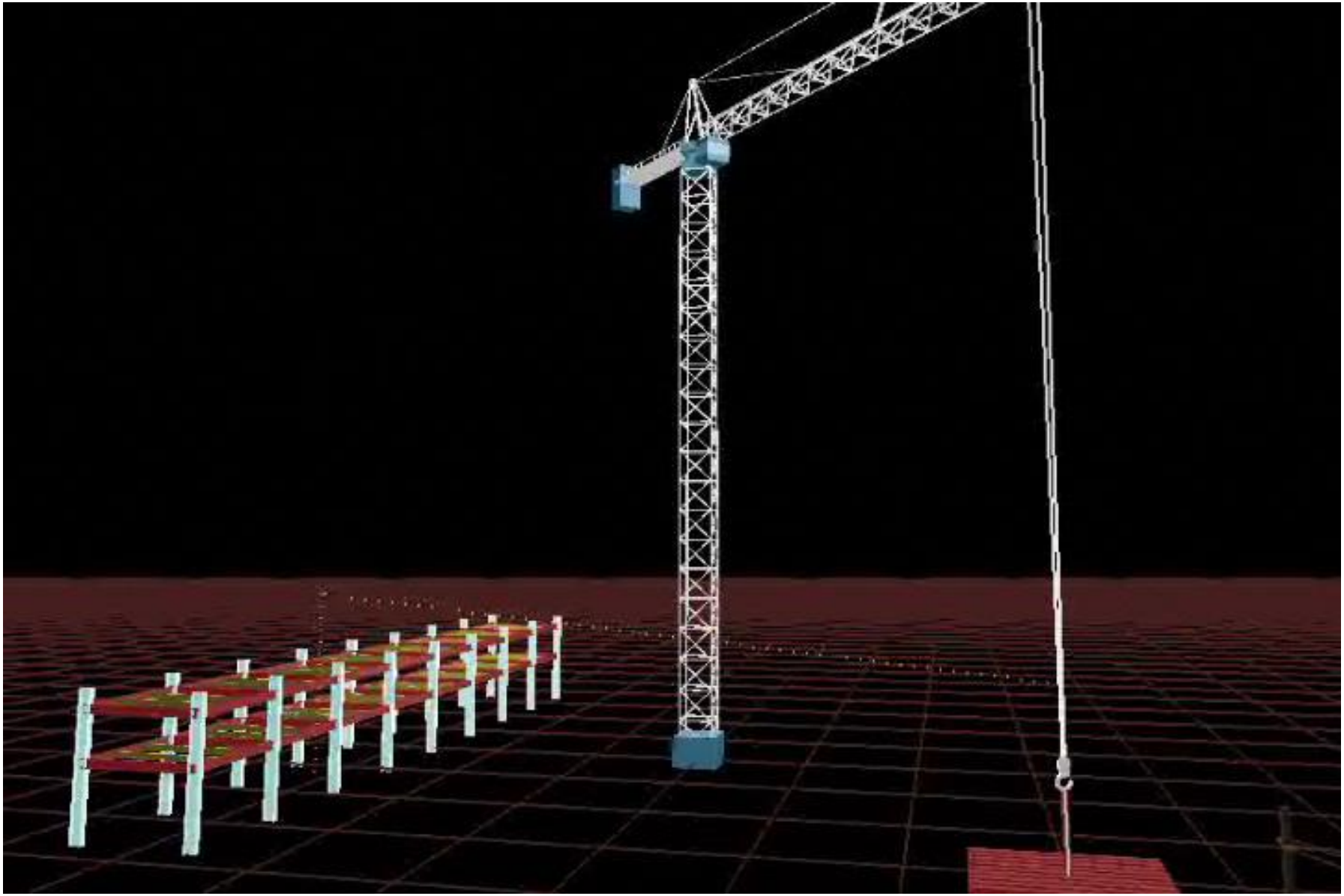
Demo: PRM method

This video is the final project in course of Motion Planning taught by Prof. Jean-Claude Latombe. Mr. Xiaoshan Pan is another team member of the project

How to find an erection path?

1. QuickLink Mothod:Try linking two trees vertical to initial and goal point

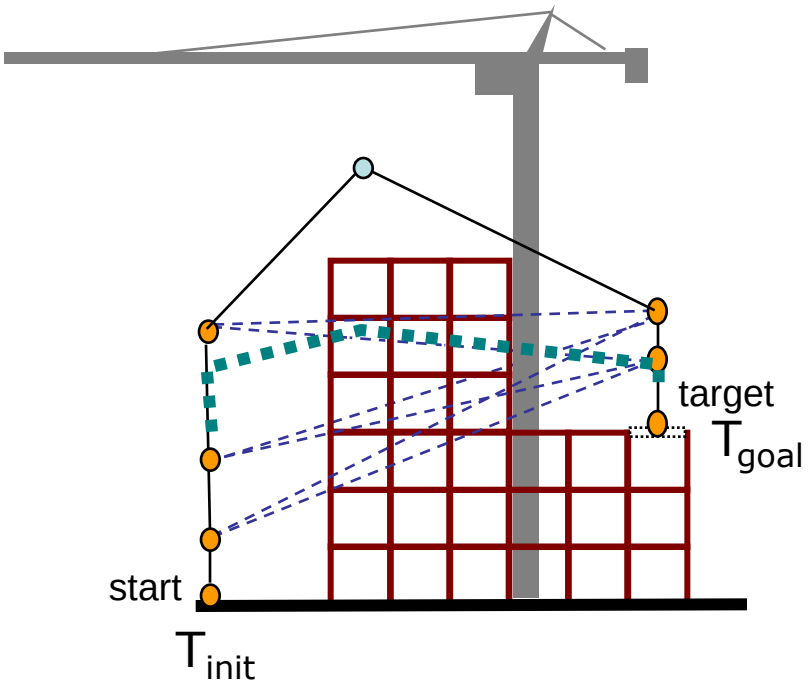


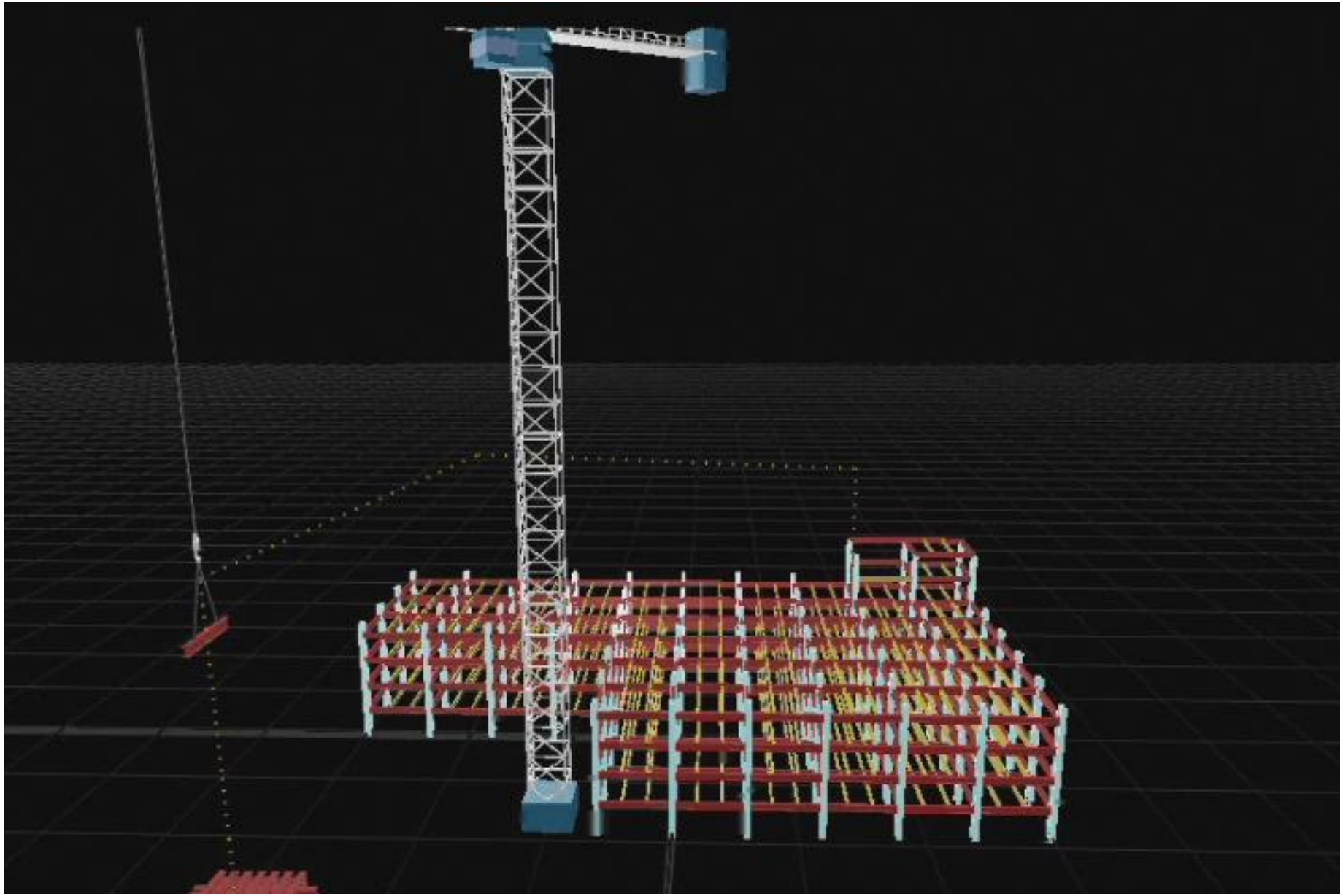


Demo: The paths generated by QuickLink Method

How to find an erection path?

2. QuickGuess Mothod: Add a random middle point between two trees and try to link them by passing a random middle point

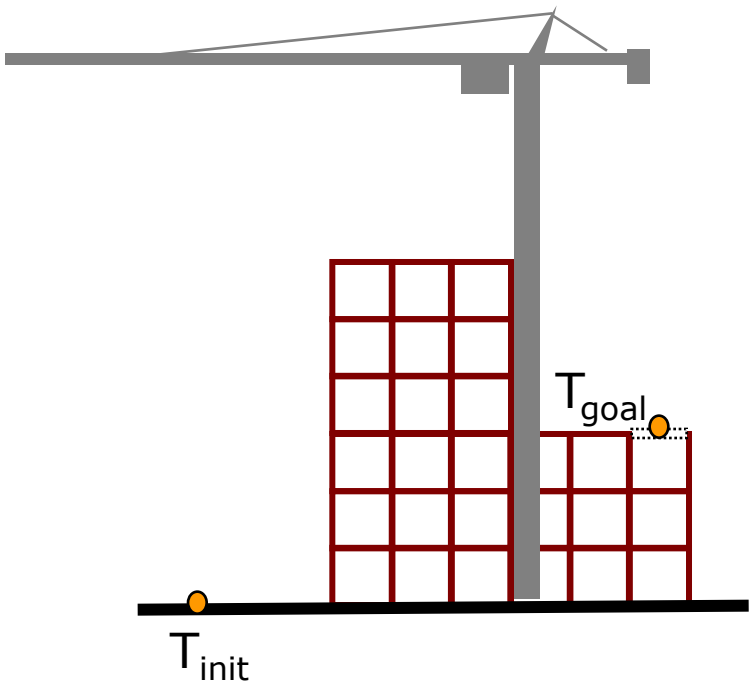




Demo: Collision-free paths found by using QuickGuess method

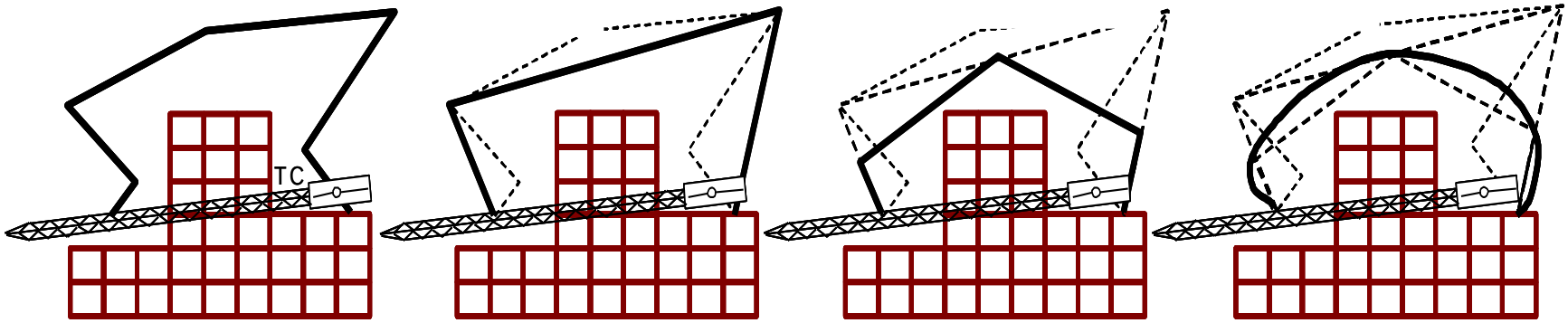
How to find an erection path?

3. Modified Random Method: Sample more points in the region with higher possibility to find a path



How to refine an erection path?

The process to refine a collision-free path



(a)

Collision-free path without any refining

(b)

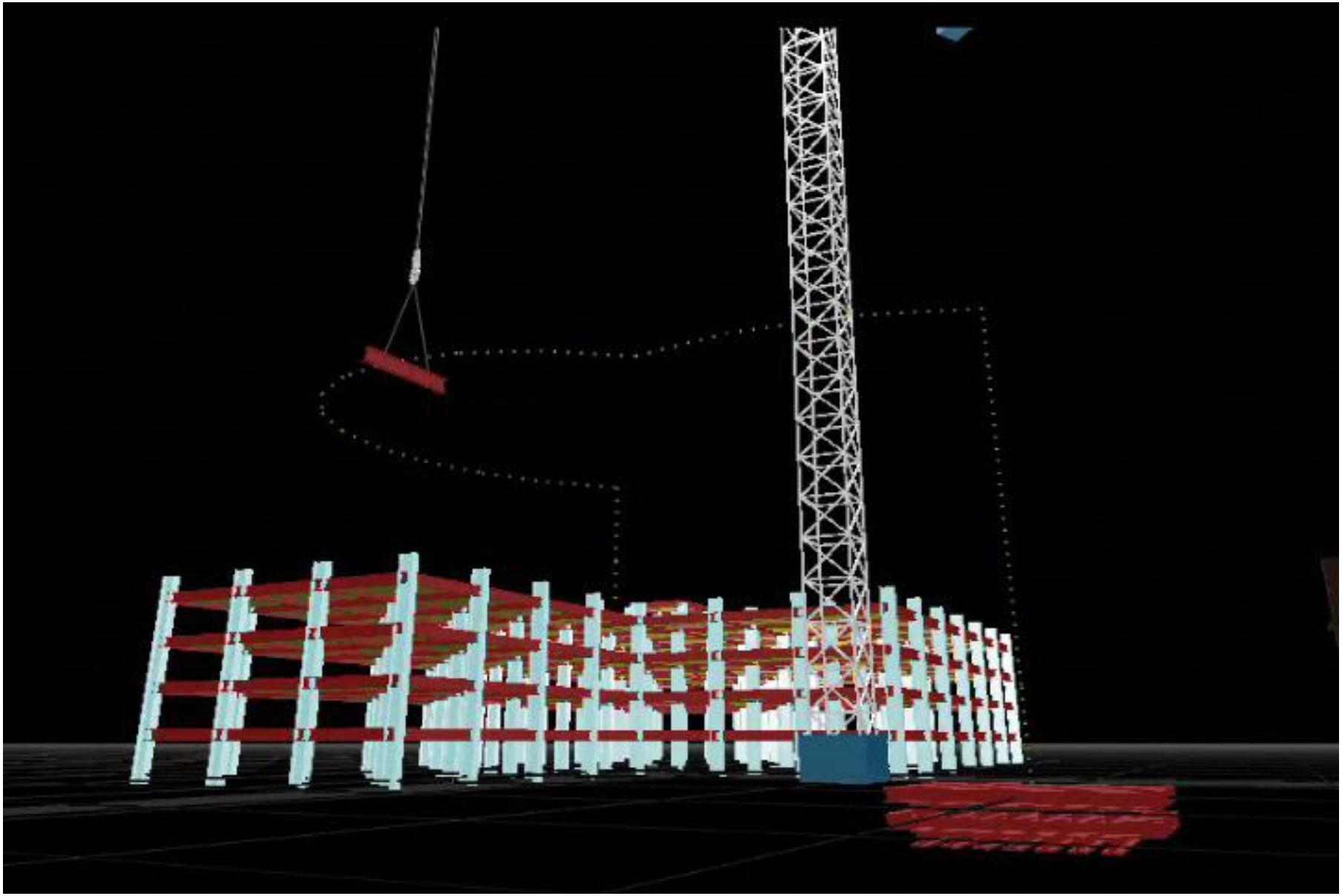
Eliminate redundant nodes in the path

(c)

Smoothen the path reduce sharp angles

(d)

Replace the straight line by curves



Demo: Refined erection paths

Question?

Course website

http://robot.caece.net