# Finding Optimal Robot Motion

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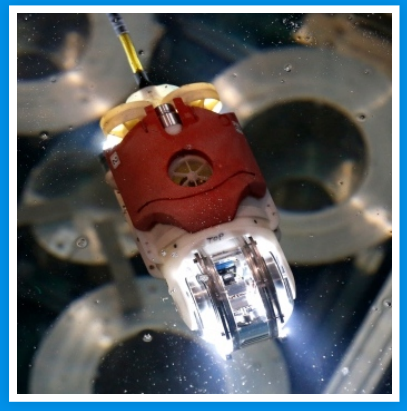
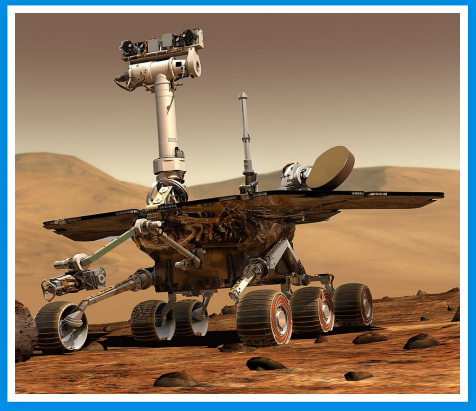
**January 22th, 2018**

RICE





Benefits of Robots:

- can assist people with disabilities/immobility
- can complete tasks that are unsafe or impossible for humans

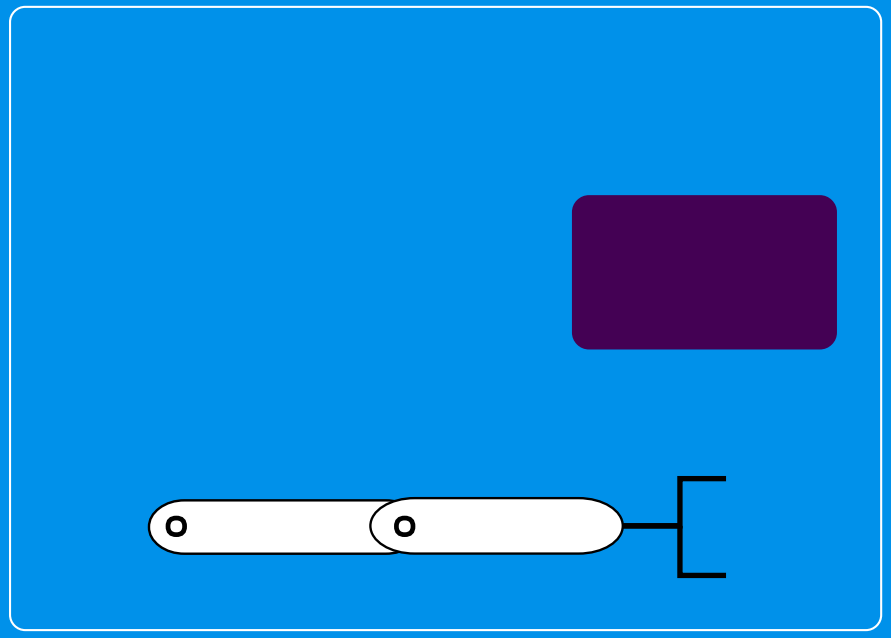
To reliably use robots in uncontrolled environments, teleoperation is the current best choice

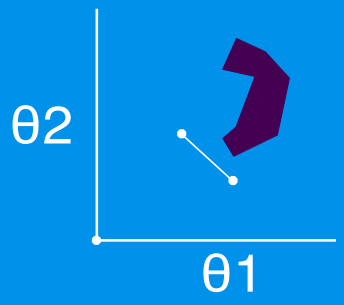
- Limits deployment to skilled operators

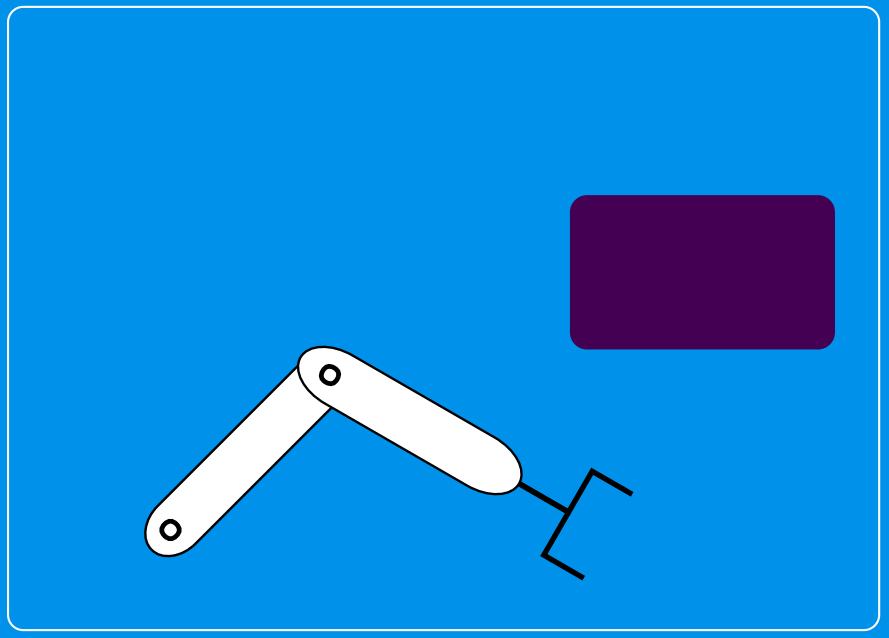
Automating these tasks allows widespread deployment

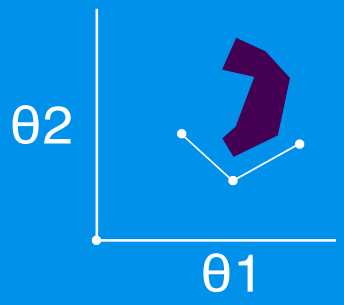
Motion planning is essential to automation.

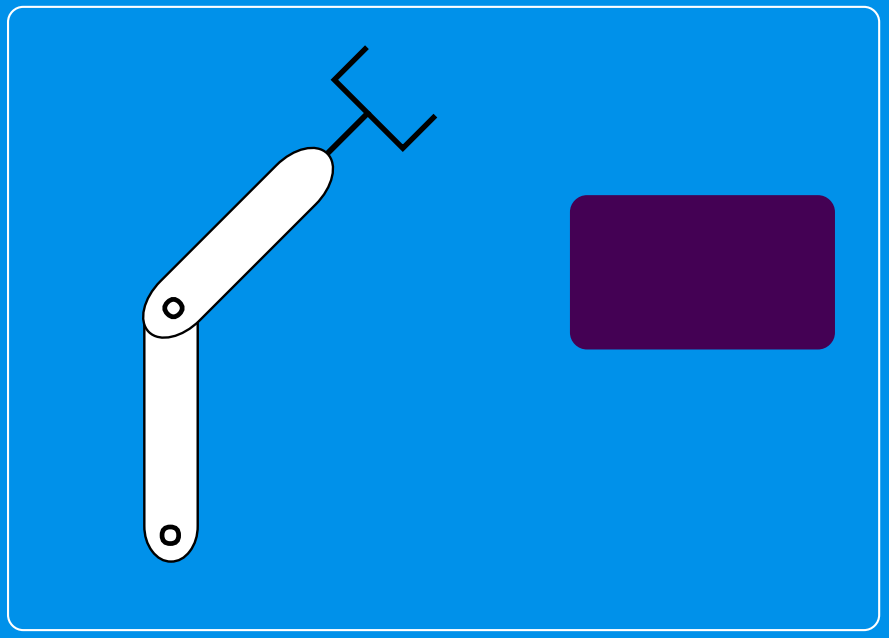

θ2
θ1




θ2
θ1

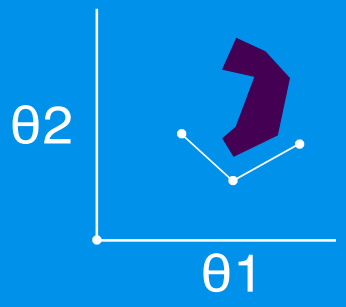


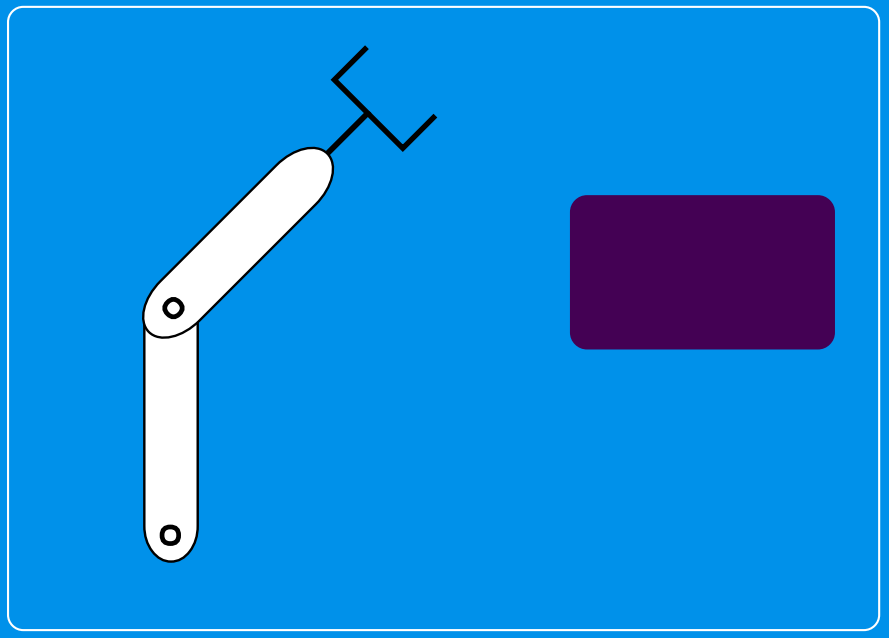

θ2
θ1



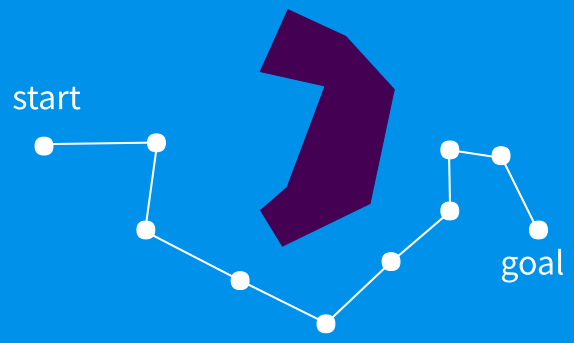
Configuration

Space



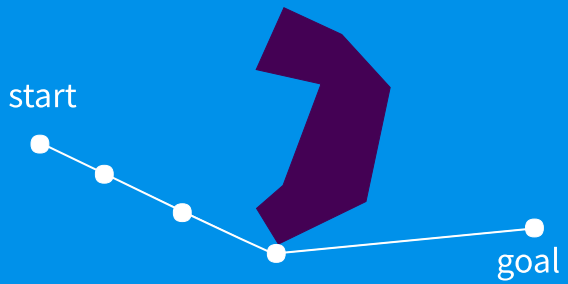



## Feasible Motion Planning




- Finds a connected path from start to goal
- Doesn't collide with any obstacles

## Optimal Motion Planning




- Assigns a cost to every path

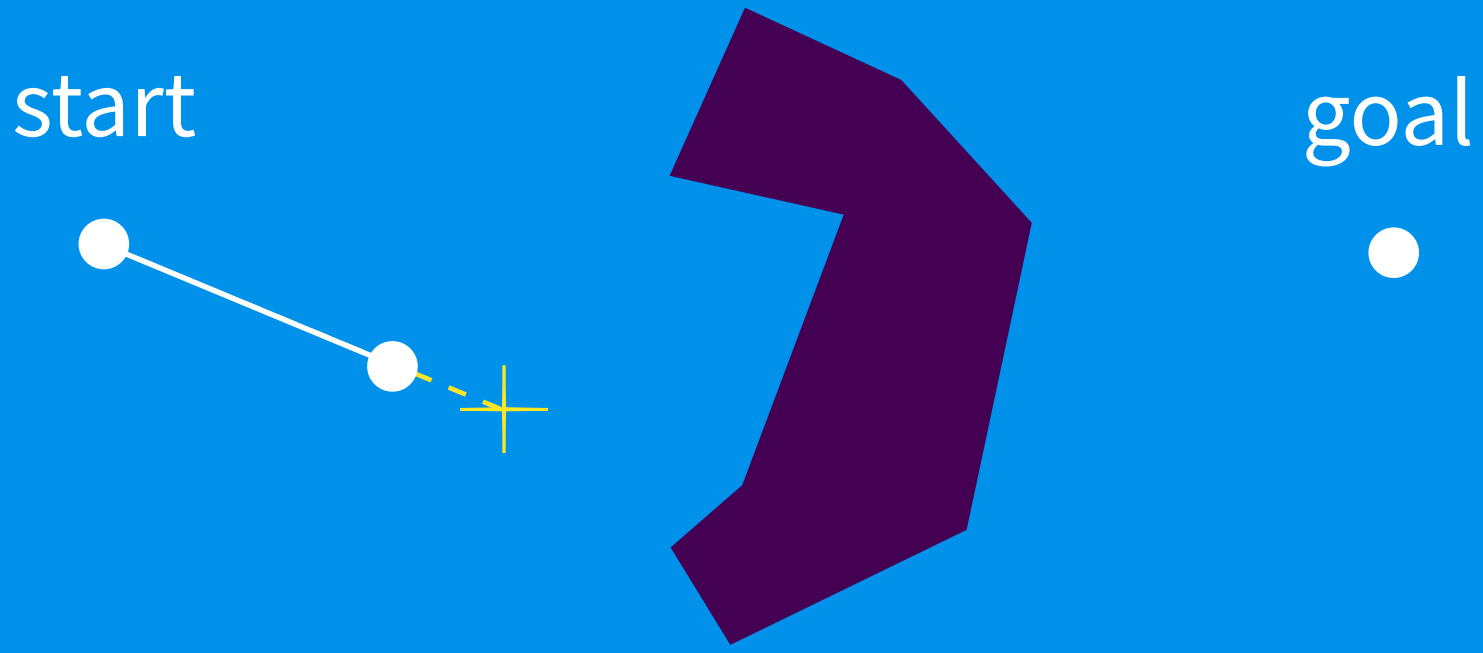
$$C : \sigma \rightarrow \mathbb{R}$$

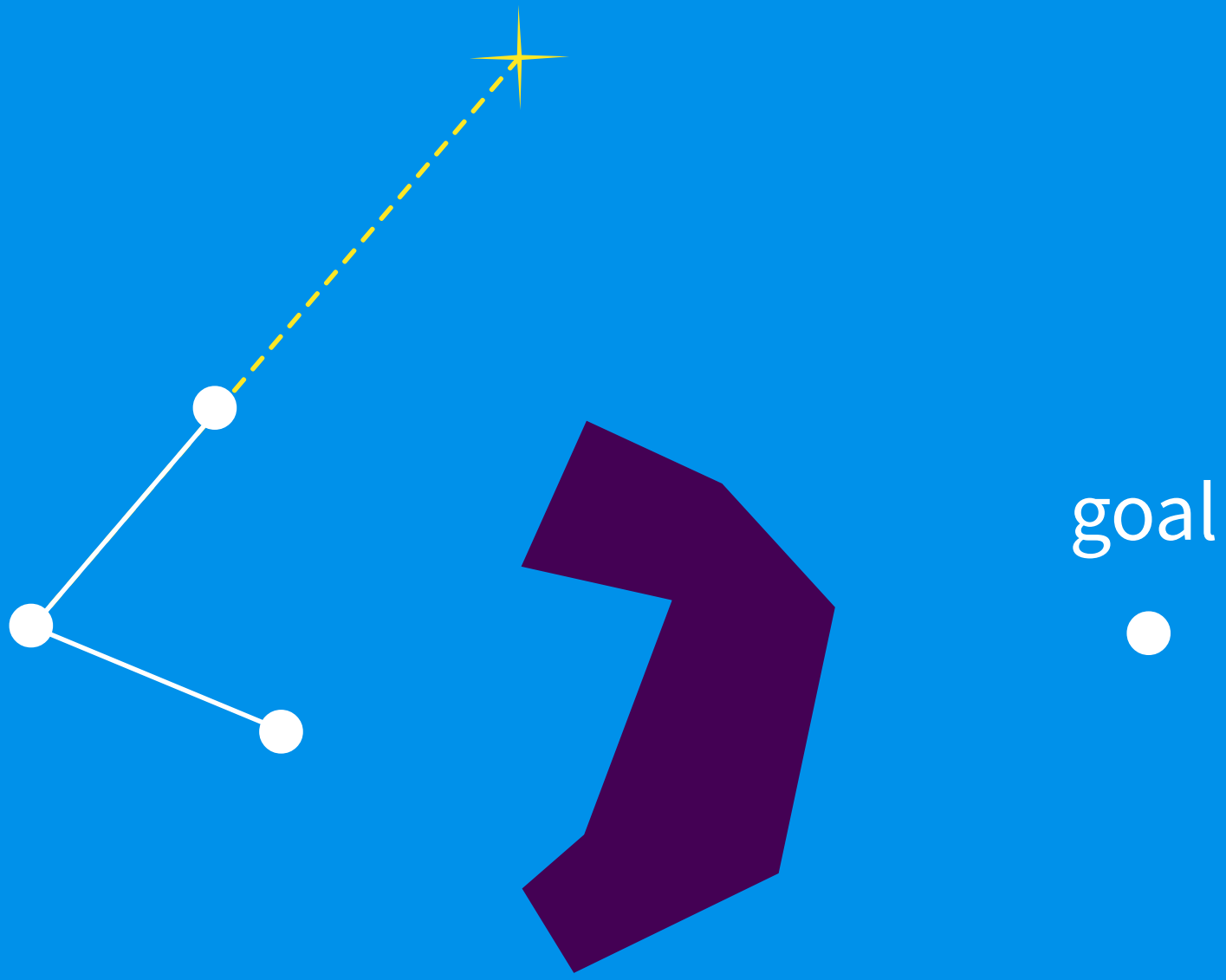
- Finds a feasible path that minimizes the cost

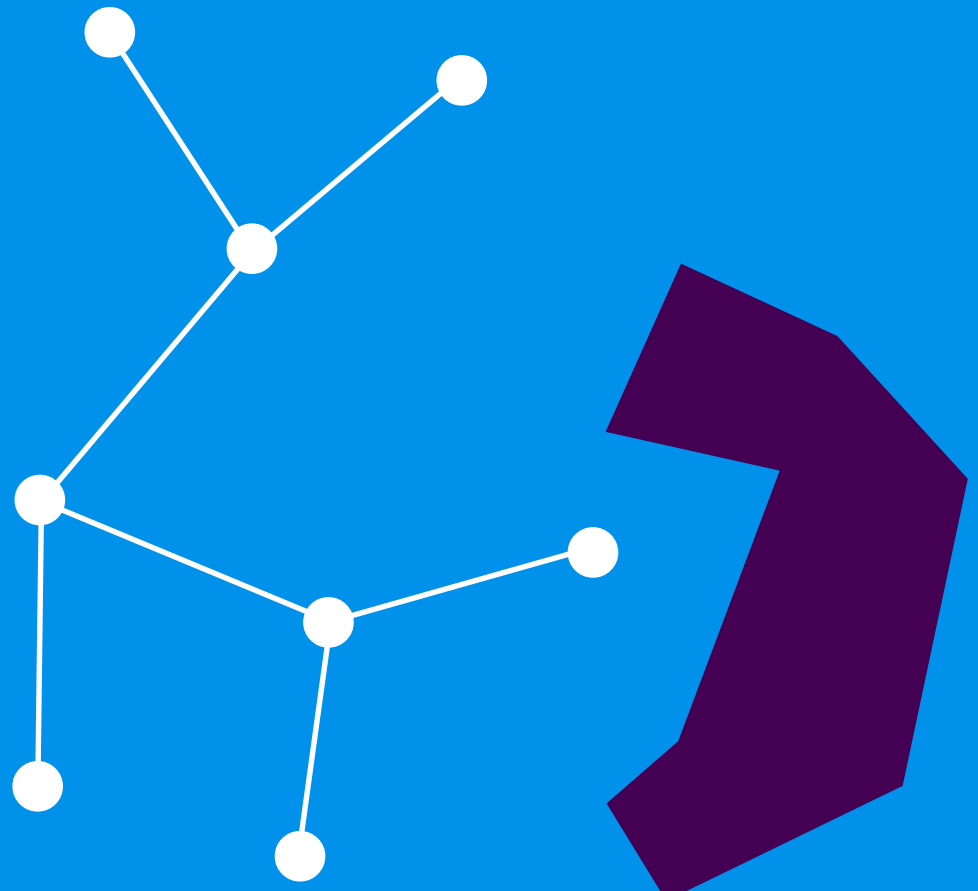
- Sampling Based Planners (Kavraki, 1994, LaValle, 1998)
- Optimization Based Planners (Ratliff et al., 2009, Kalakrishnan et al., 2011)


start
goal

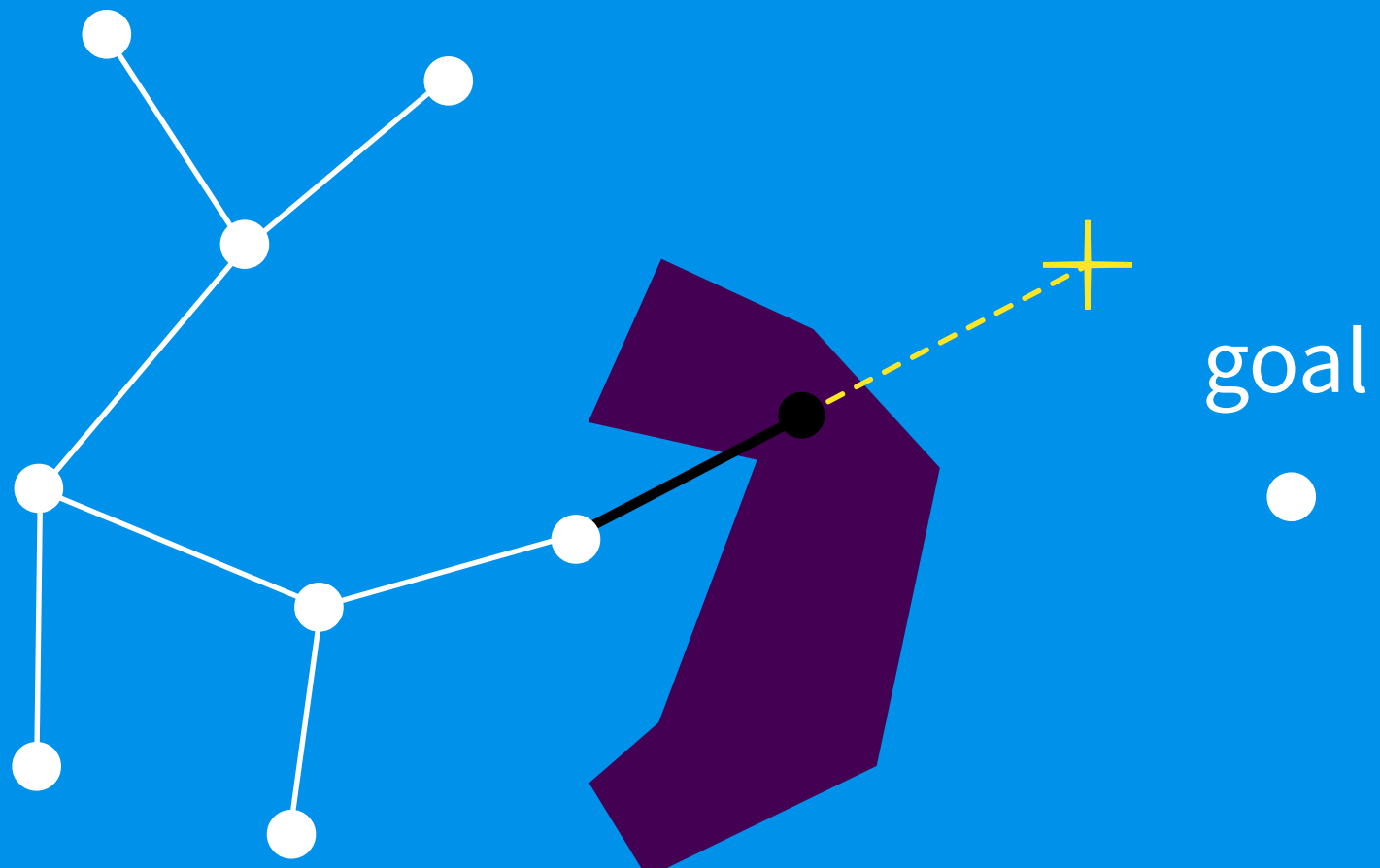

start
sample
goal


start
goal

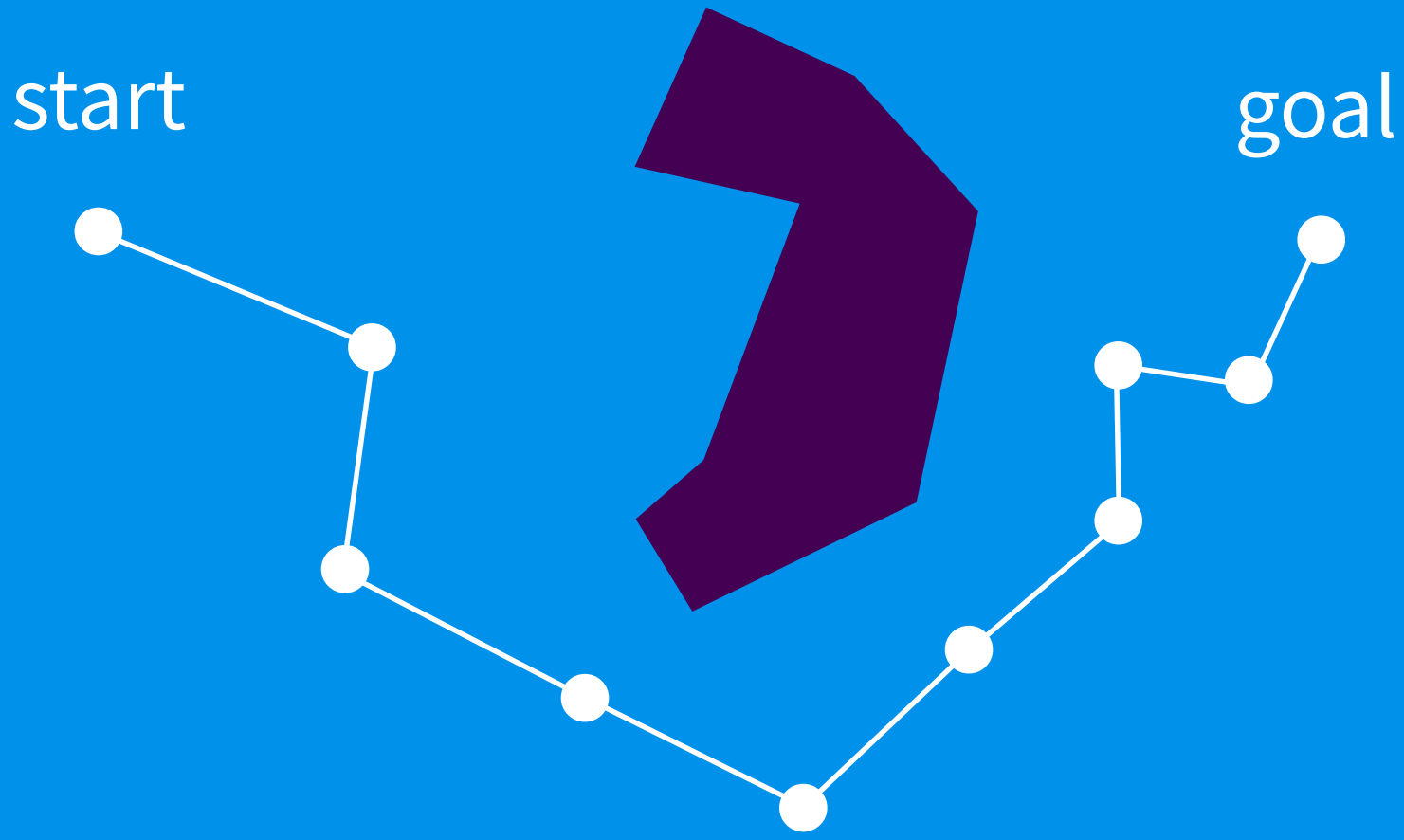

goal

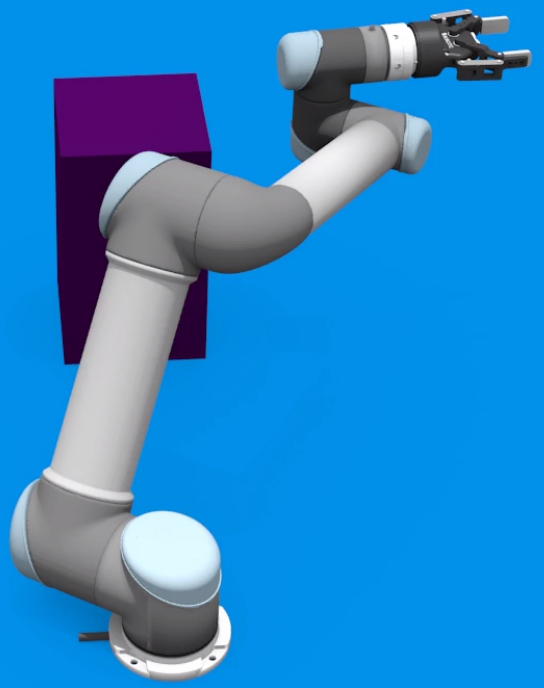


goal

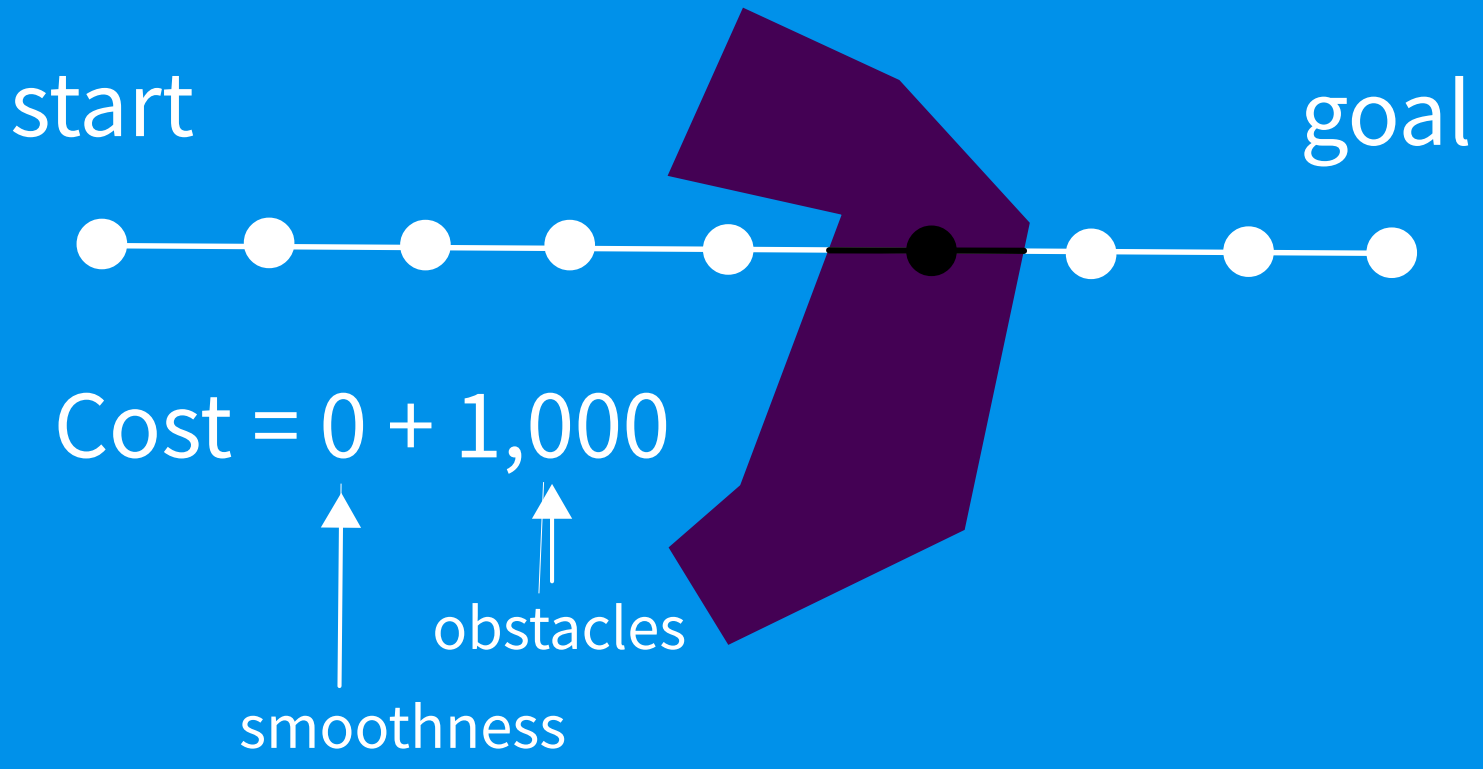

goal

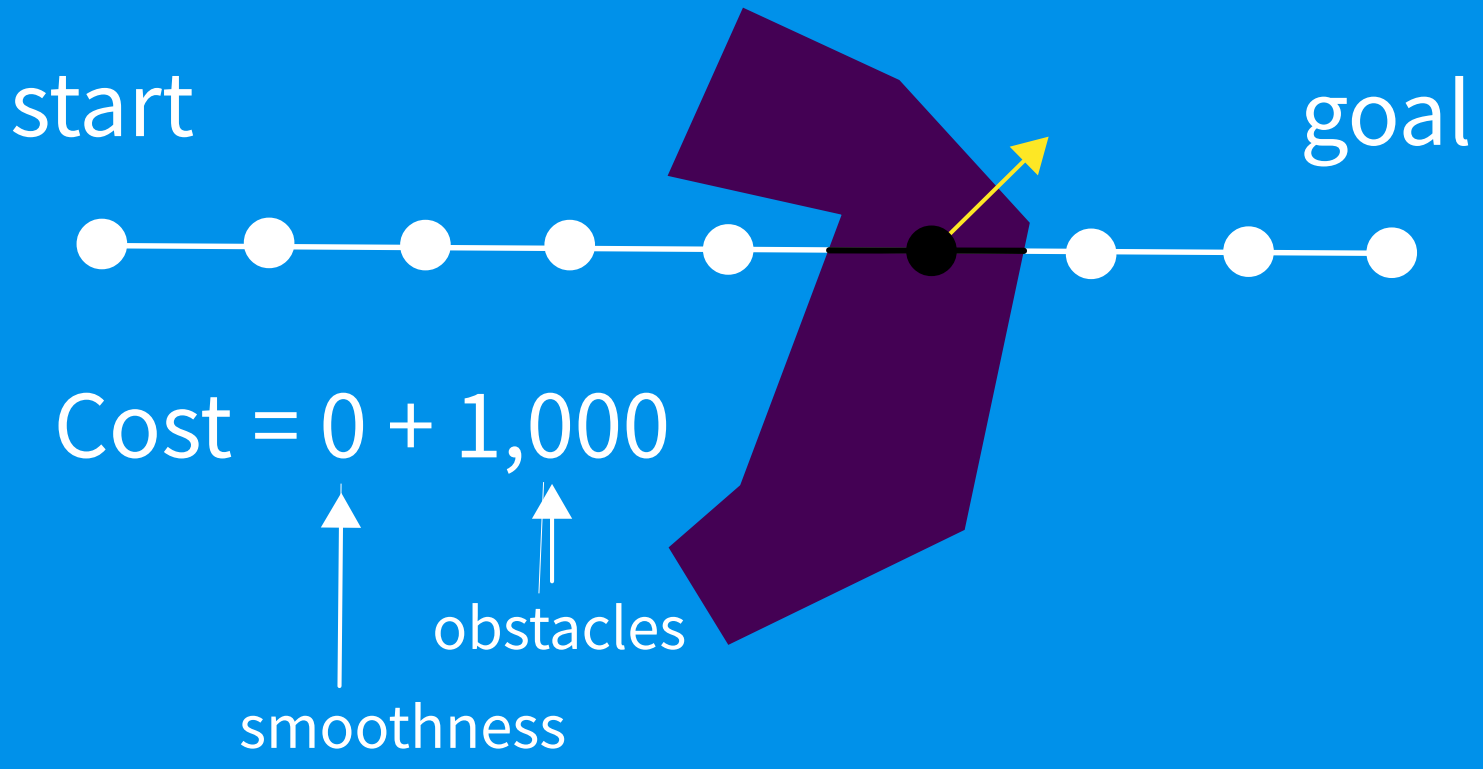

goal

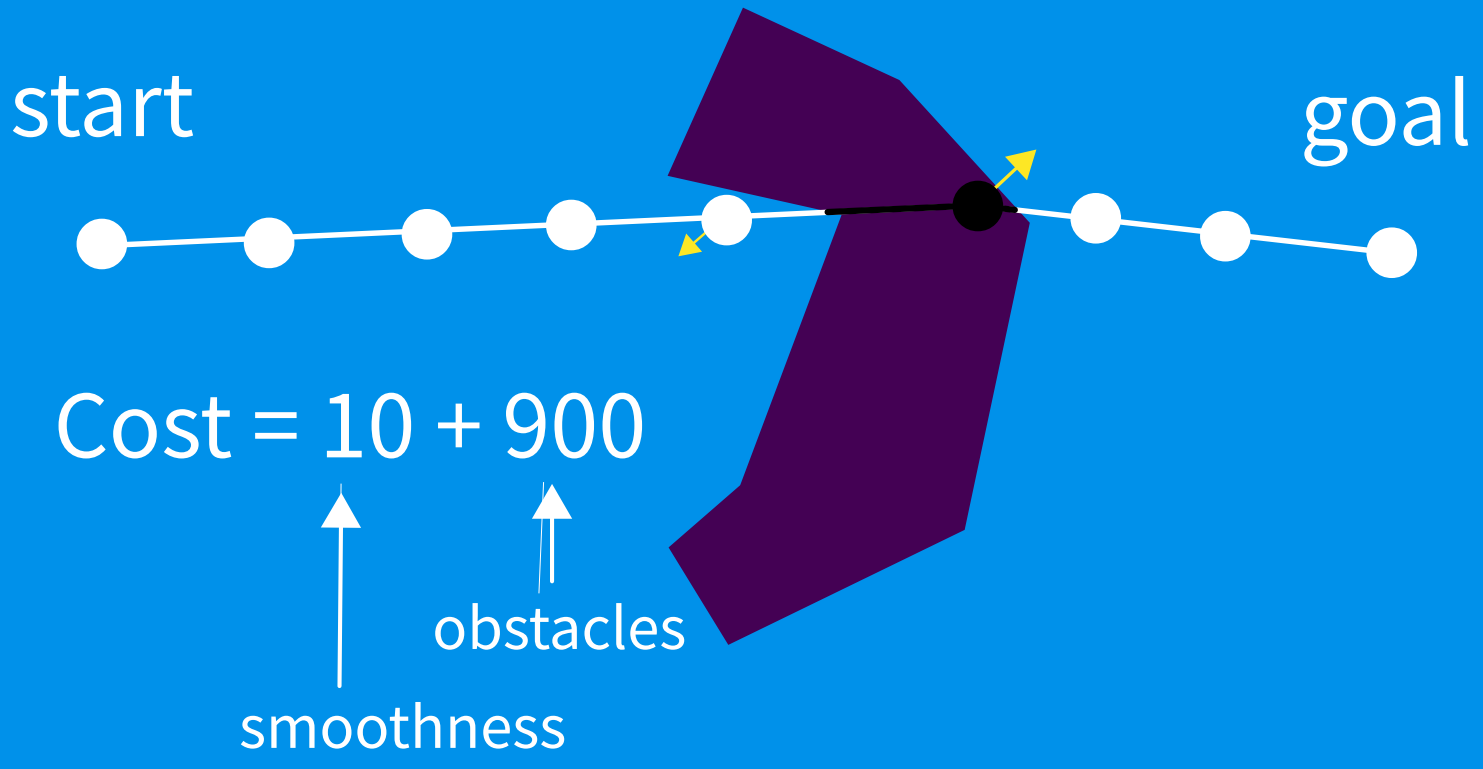

start
goal

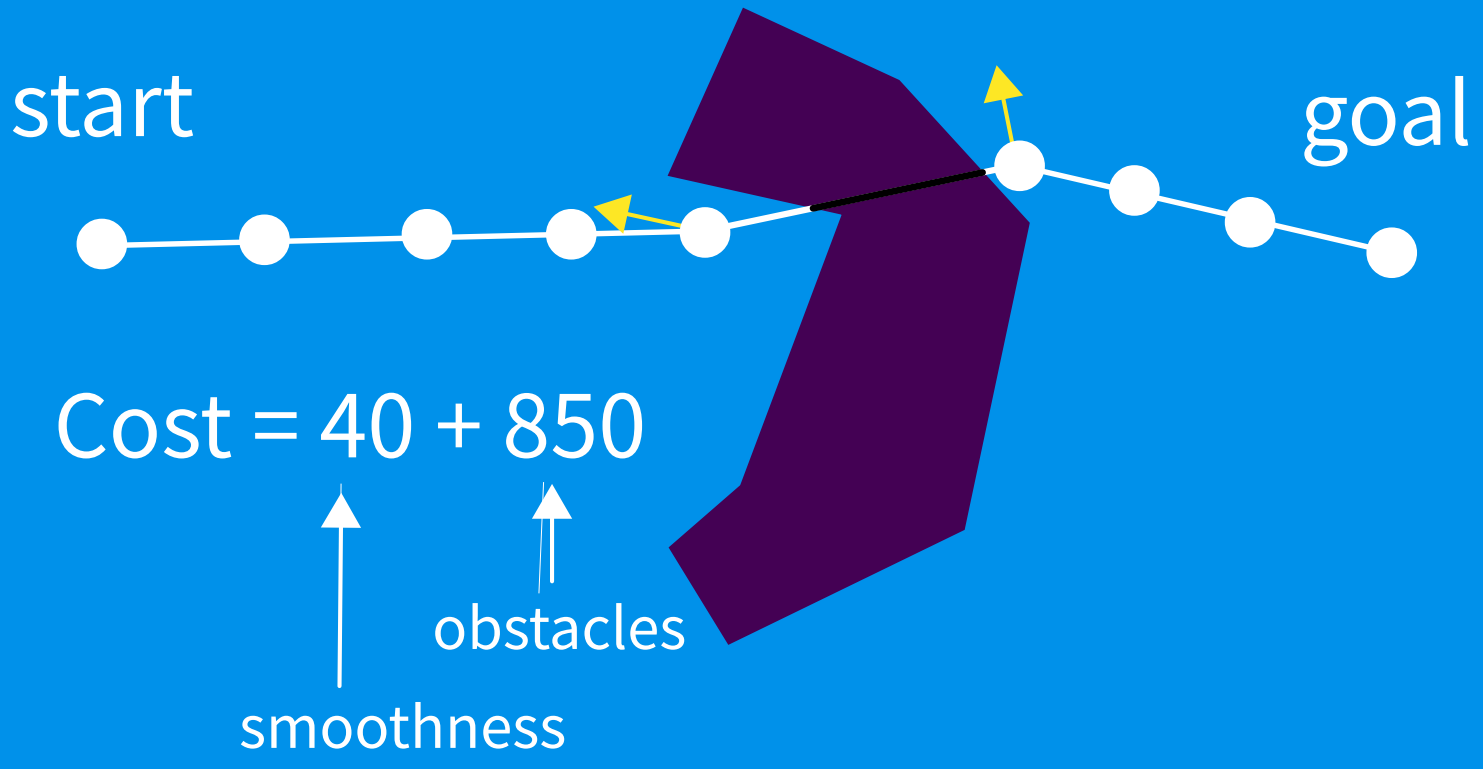


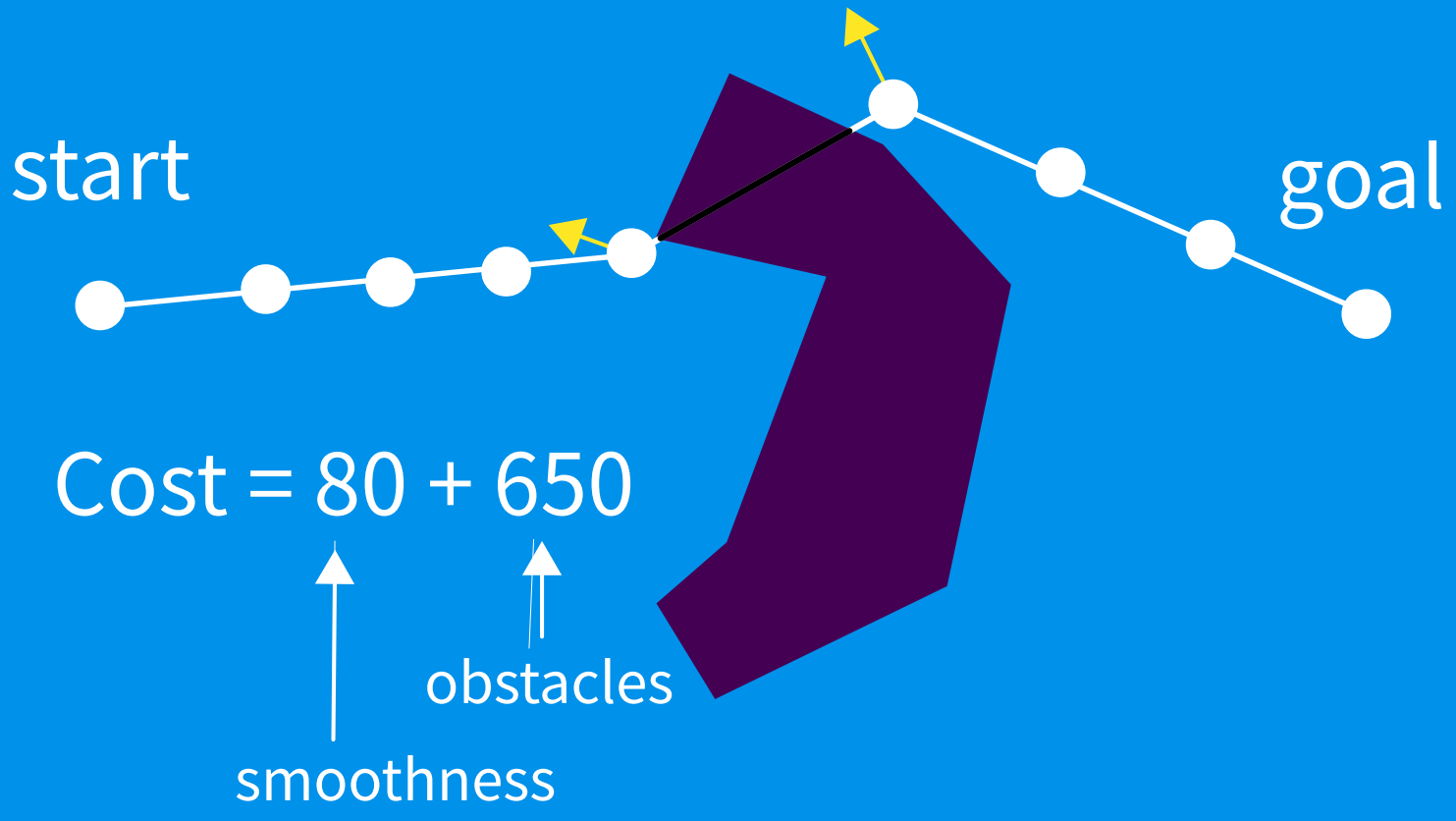

start
goal

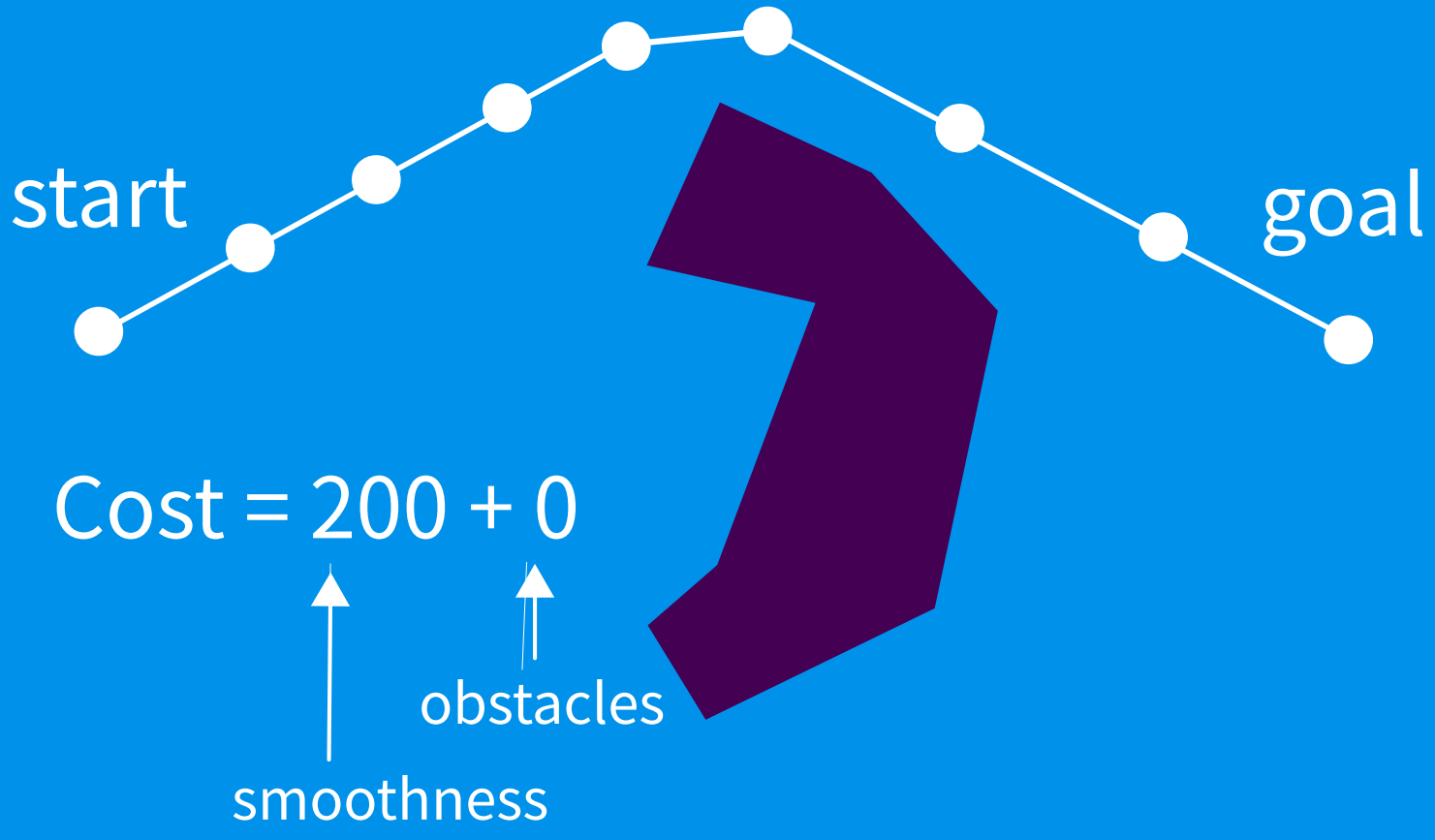

start
goal
Cost = 0 + 1,000
obstacles
smoothness

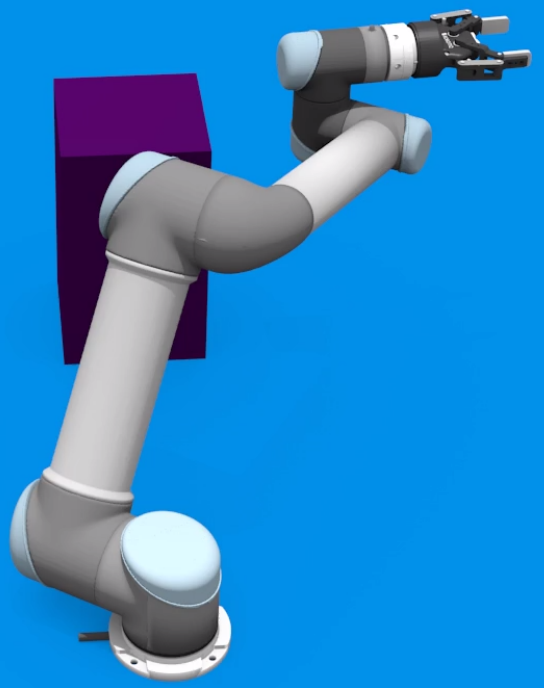

start
goal
Cost = 0 + 1,000
obstacles
smoothness


start
goal
Cost = 10 + 900
obstacles
smoothness

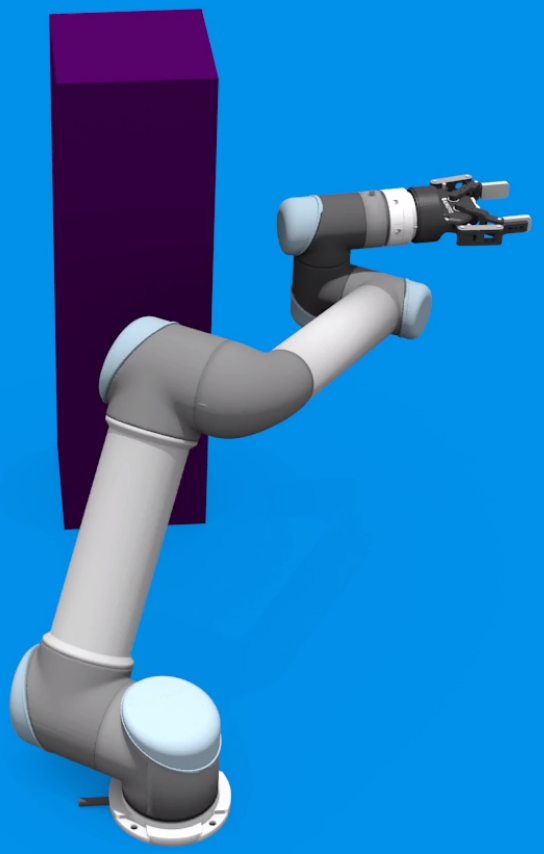

start
goal
Cost = 40 + 850
obstacles
smoothness


start
goal
Cost = 80 + 650
obstacles
smoothness

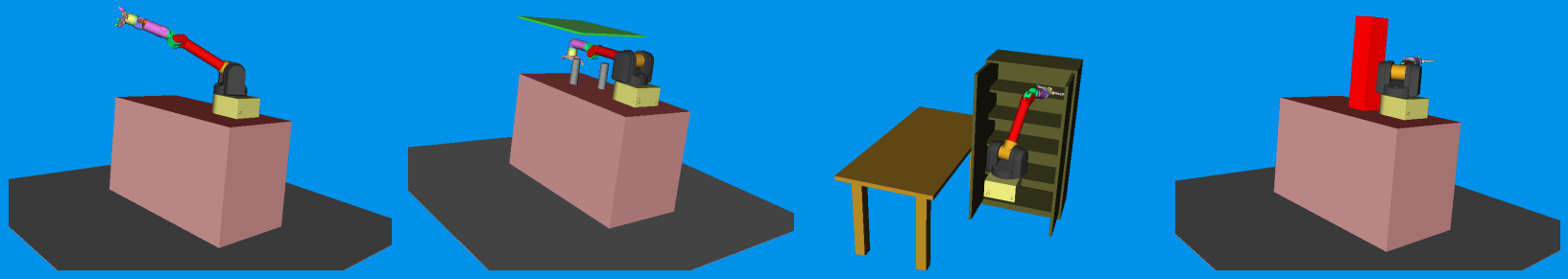

start
goal
Cost = 200 + 0
obstacles
smoothness



Only finds feasible path 20% of the time with larger column



Currently, few rigorous comparisons in the literature



Planners:

- Sampling: RRT-Connect, PRM, BIT*
- Optimization: TrajOpt, CHOMP, GPMP2

TrajOpt = 6/8 scenes

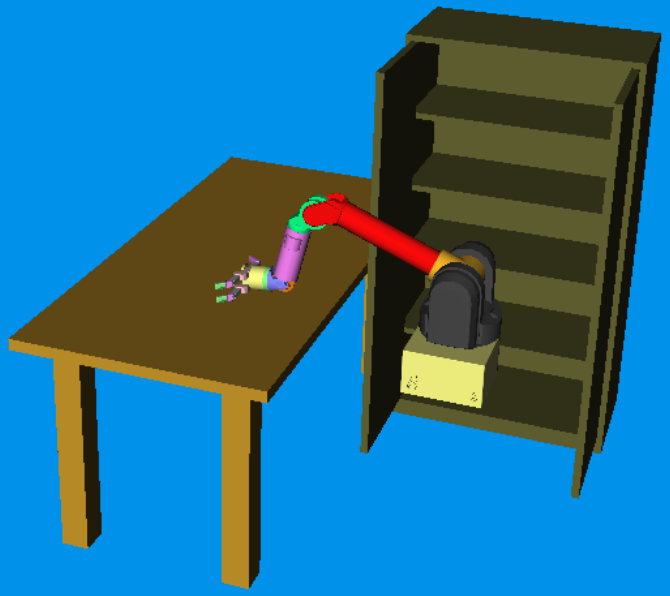
CHOMP = 4/8 scenes

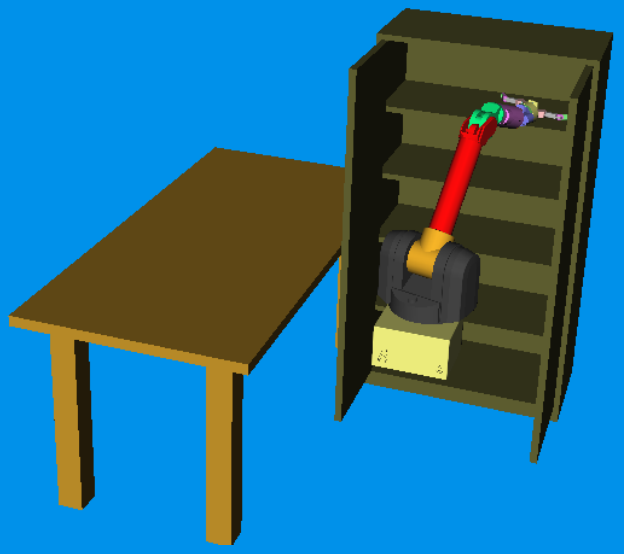
GPMP2 = 7/8 scenes

RRT-Connect = 8/8 scenes

PRM = 8/8 scenes, 87.5% of the tries

BIT* = 8/8 scenes





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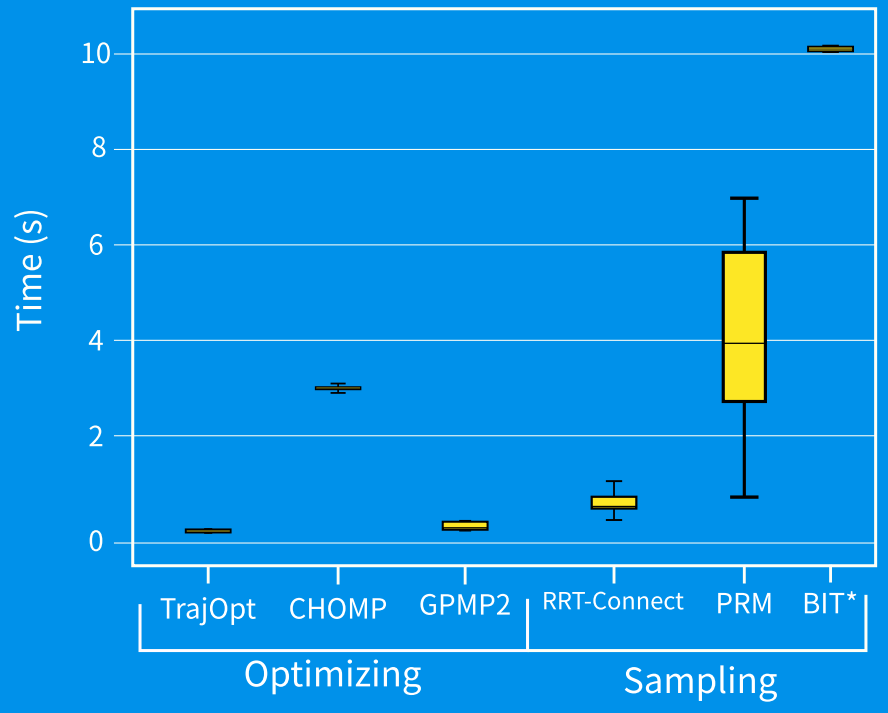
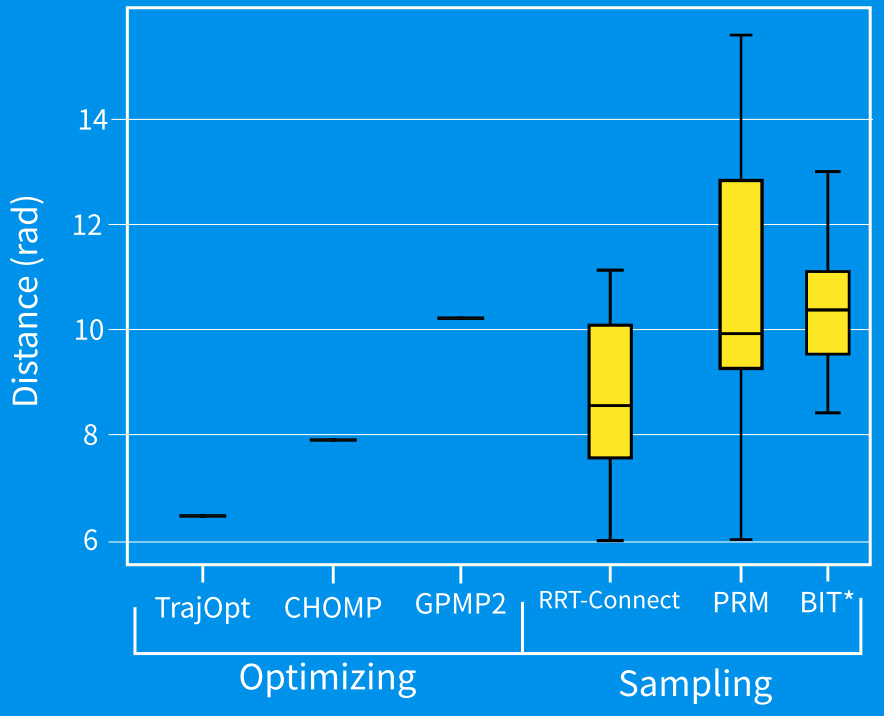
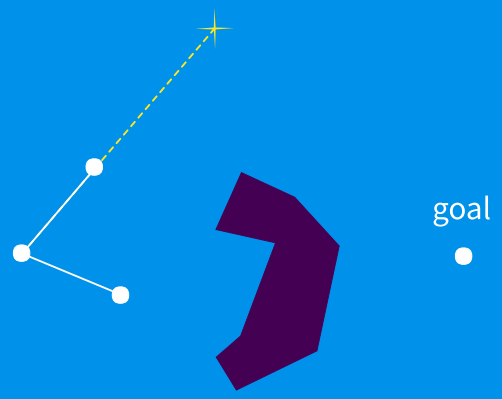

Time (s)
10
8
6
4
2
0
TrajOpt
CHOMP
GPMP2
RRT-Connect
PRM
BIT*
Optimizing
Sampling


Distance (rad)
14
12
10
8
6
TrajOpt
CHOMP
GPMP2
RRT-Connect
PRM
BIT*
Optimizing
Sampling



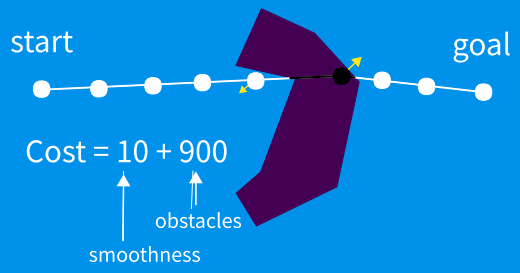


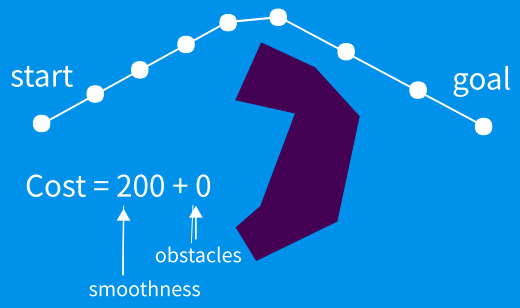
## Pros

- Probabilistic Completeness
- Very reliable
- Can find optimal paths

## Cons

- Must smooth the path after finding it
- Finding optimal paths is time consuming




## Pros

- 5-10x Faster
- Quality, smooth paths

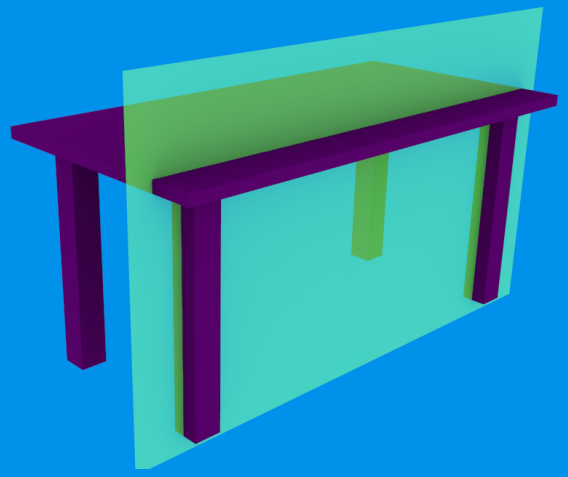
## Cons

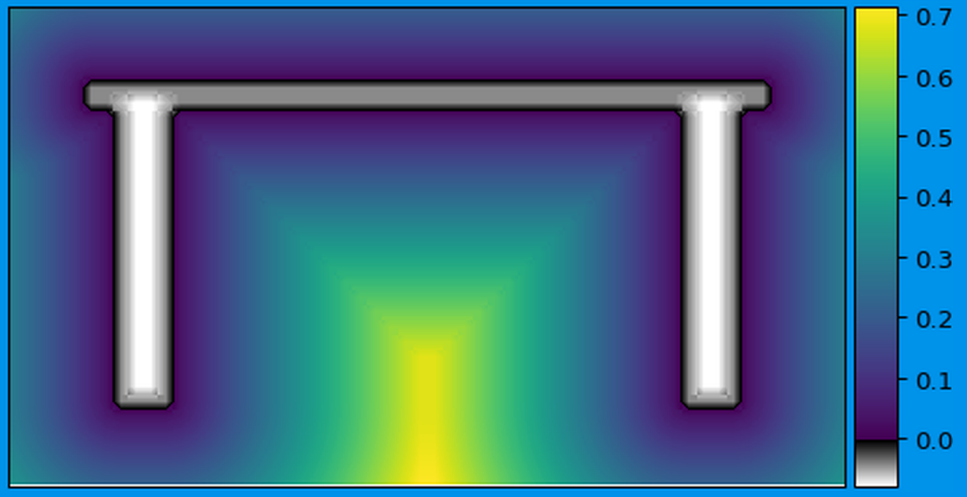
- No guarantee of finding a feasible path
- Not as reliable as sampling planners

Optimization planners do special 'tricks' to speed up planning

What really makes optimization planners faster?

- Discretizes 3D space into a fine grid
- Calculates distance and gradient from each cell to closest obstacle border
  - > 0 if the cell lies outside of the obstacle
  - < 0 if the cell is inside an obstacle

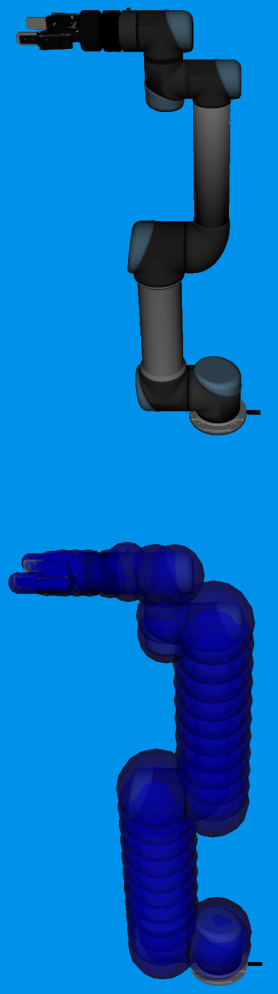




Usually done precisely using collision libraries (FCL, Bullet, etc)

Can be approximated using signed distance fields

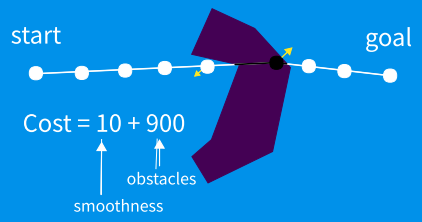
Approximating the robot using spheres makes getting collision information O(1)



Abstract signed distance fields and compare speed ups in sampling planners

Test on a wider variety of planning problems

Use sampling and optimization together: quality motion and faster convergence


Possible sources of performance in optimization planners is under investigation

Best motion planner is dependent on your specifications