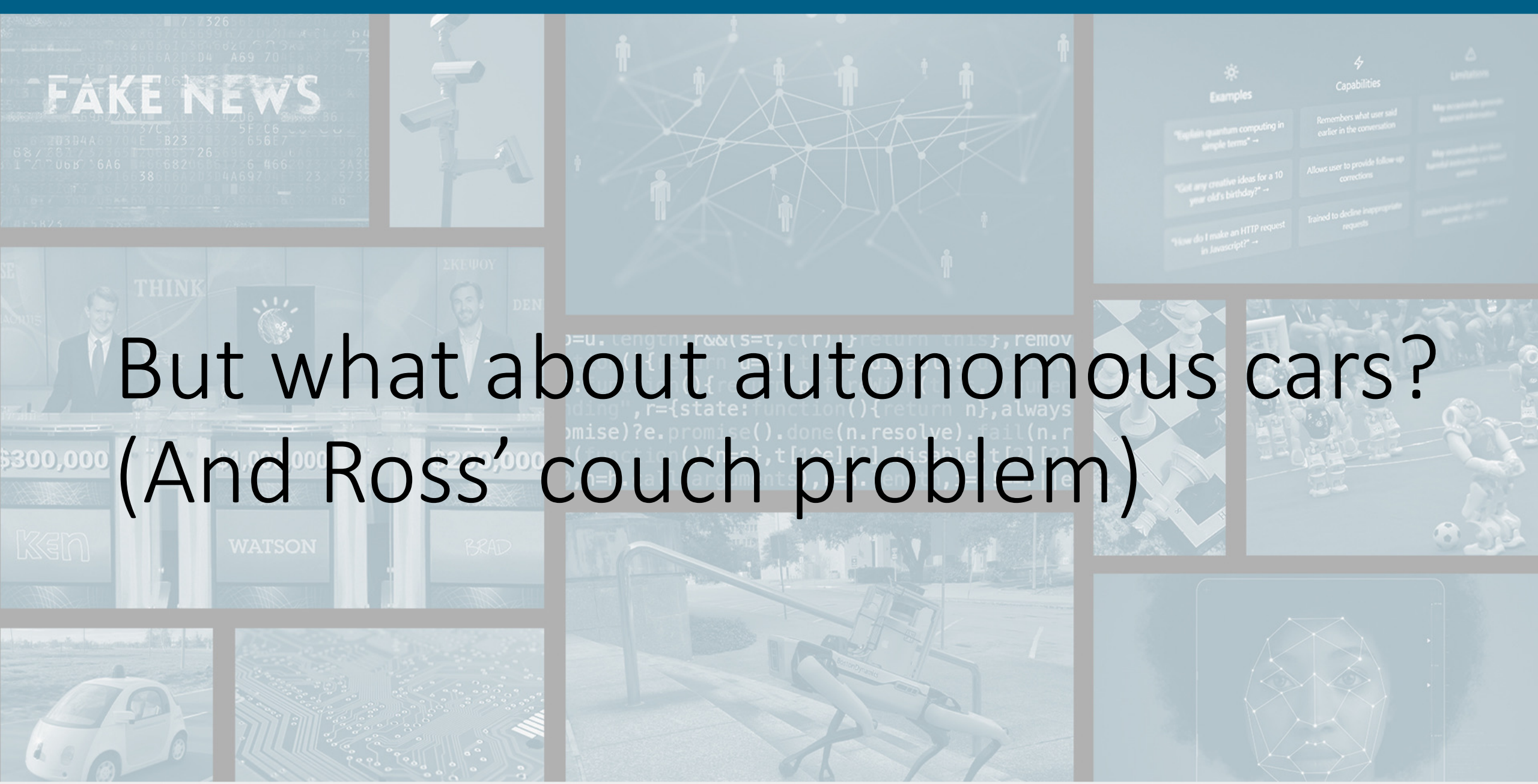


But what about autonomous cars? (And Ross' couch problem)

The Planning Problem *Applied To Autonomous Driving*

Given:

1. An ***initial state*** of the world ***=> The current car pose & velocity***
2. A set of ***available actions***, their requirements, and their effects ***=> Safe driving actions (steering, throttle)***
3. A ***goal state*** ***=> Driving destination***

Compute:

A ***valid sequence of actions*** that starts from the initial state and terminates at the goal state ***=> Plan = sequence of driving actions***

Planning Via Search (Revision)

1. Enumerate all possible actions available, and the resulting states
2. Check if goal state reached
3. If not, for every possible outcome, repeat step 1 for all new states

Planning Via Search (Revision)

1. Enumerate all possible actions available, and the resulting states
2. Check if goal state reached
3. If not, for every possible outcome, repeat step 1 for all new states

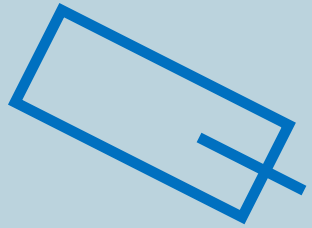
Nope, can't do that.

Problems:

- **States are continuous!**
- **Actions are continuous!**

Planning With Continuous Actions

How can we plan for a continuous sequence of motions to take the car from the start to the goal, while avoiding all obstacles?



Motion Planning
“The piano mover’s problem”

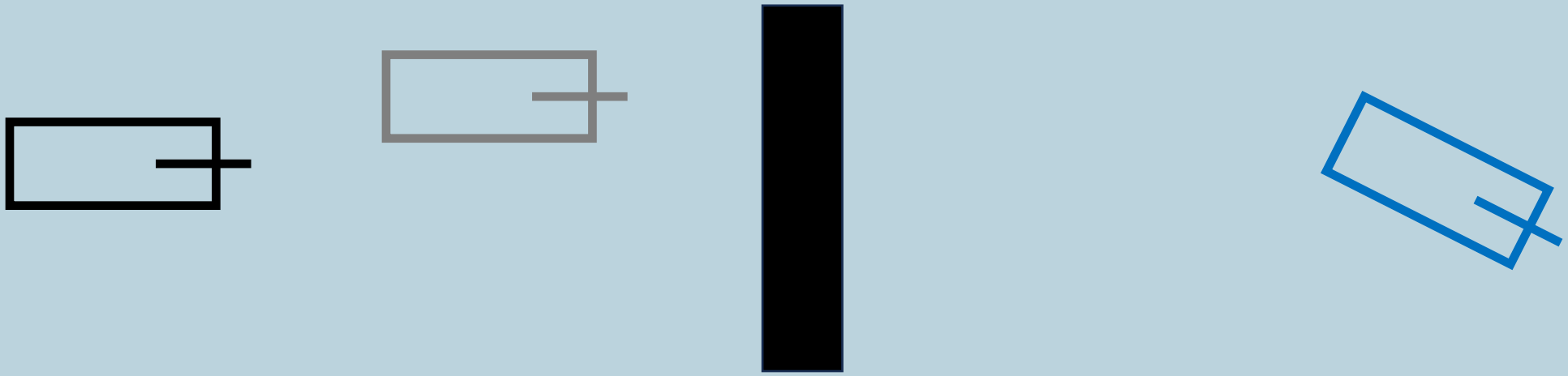
a.k.a. *Let’s help Ross plan for how to move his couch up the stairs*

Motion Planning Using Rapidly Exploring Random Trees

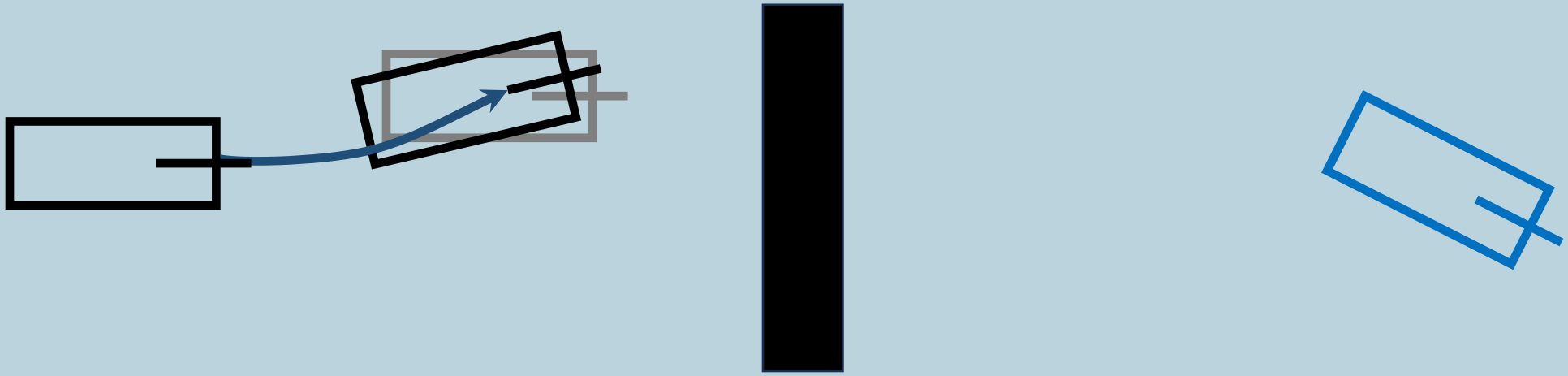
1. Randomly sample a state
2. Try to get there from the closest known pose
    1. If success, expand tree
    2. If collision, discard new pose
3. Repeat 1, 2 until goal reached

LaValle, Steven. "Rapidly-exploring random trees: A new tool for path planning." *Research Report 9811* (1998).
LaValle, Steven, and Kuffner, James. "Randomized kinodynamic planning." *The international journal of robotics research* 20.5 (2001): 378-400.

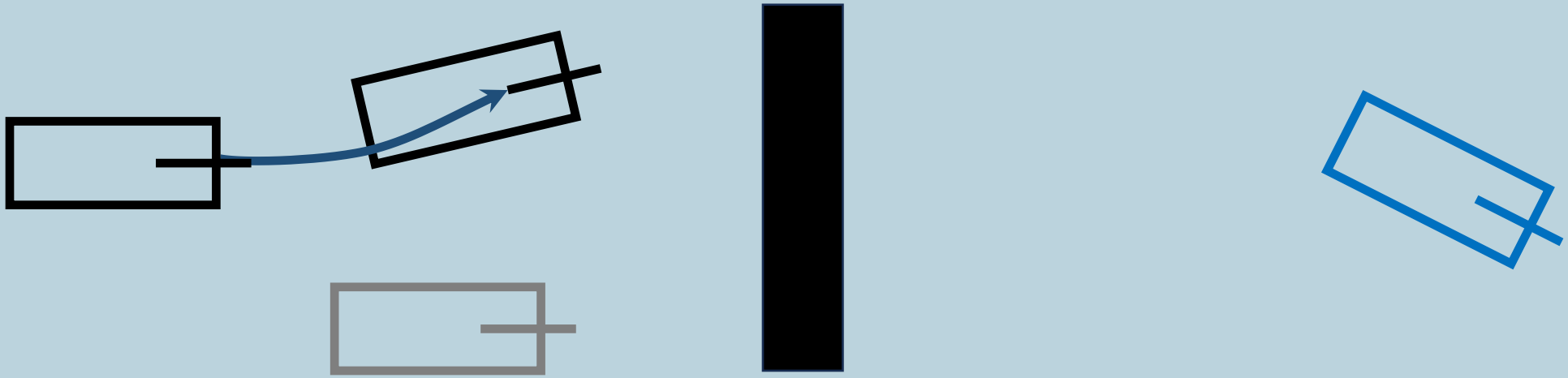
1. Randomly sample a state



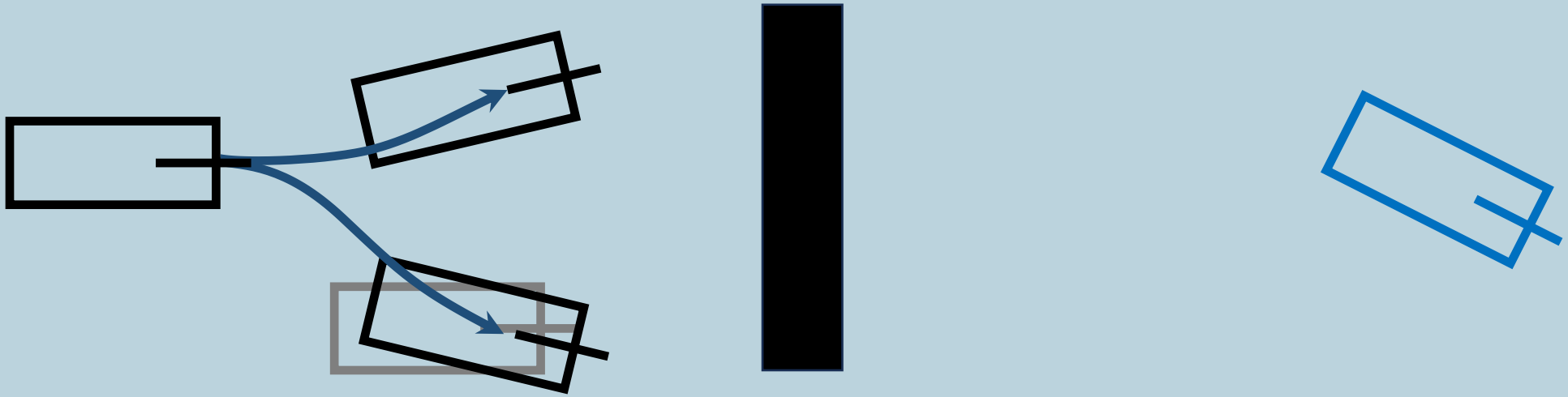
2. Try to get there from closest known pose



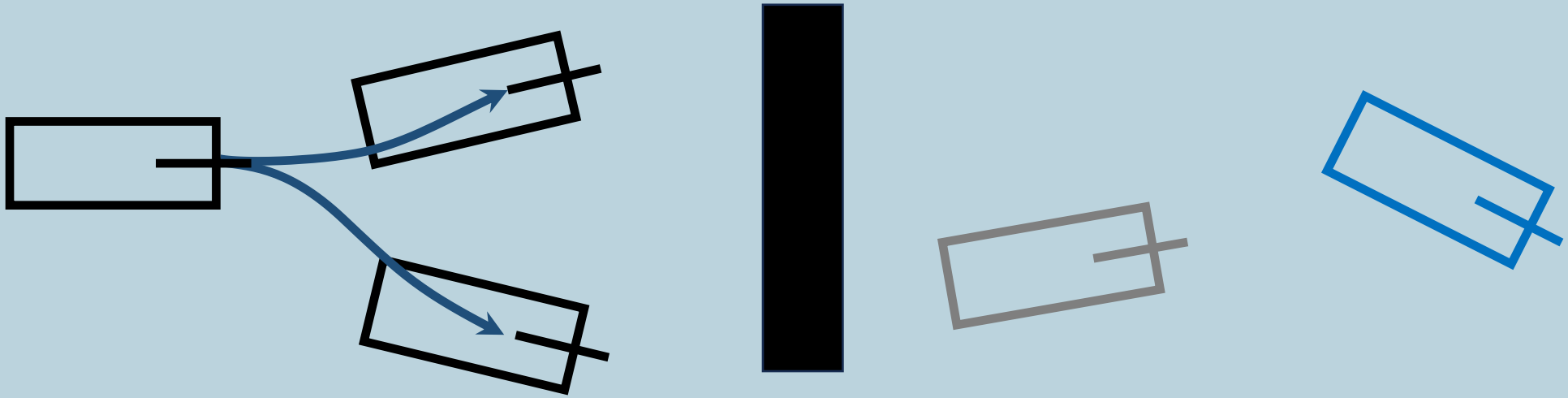
Repeat 1: Randomly sample a state



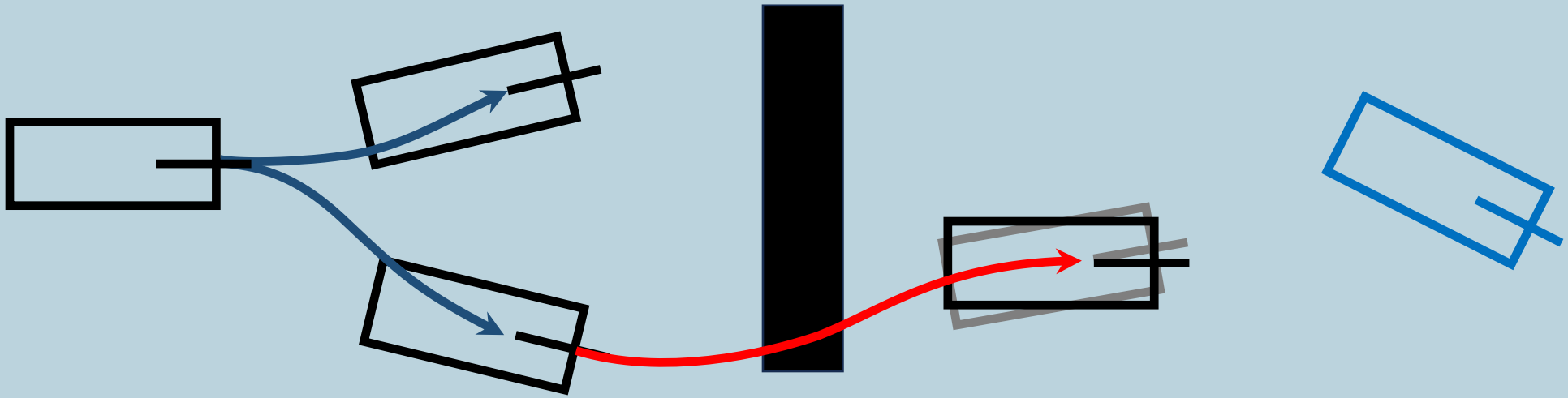
2. Try to get there from closest known pose



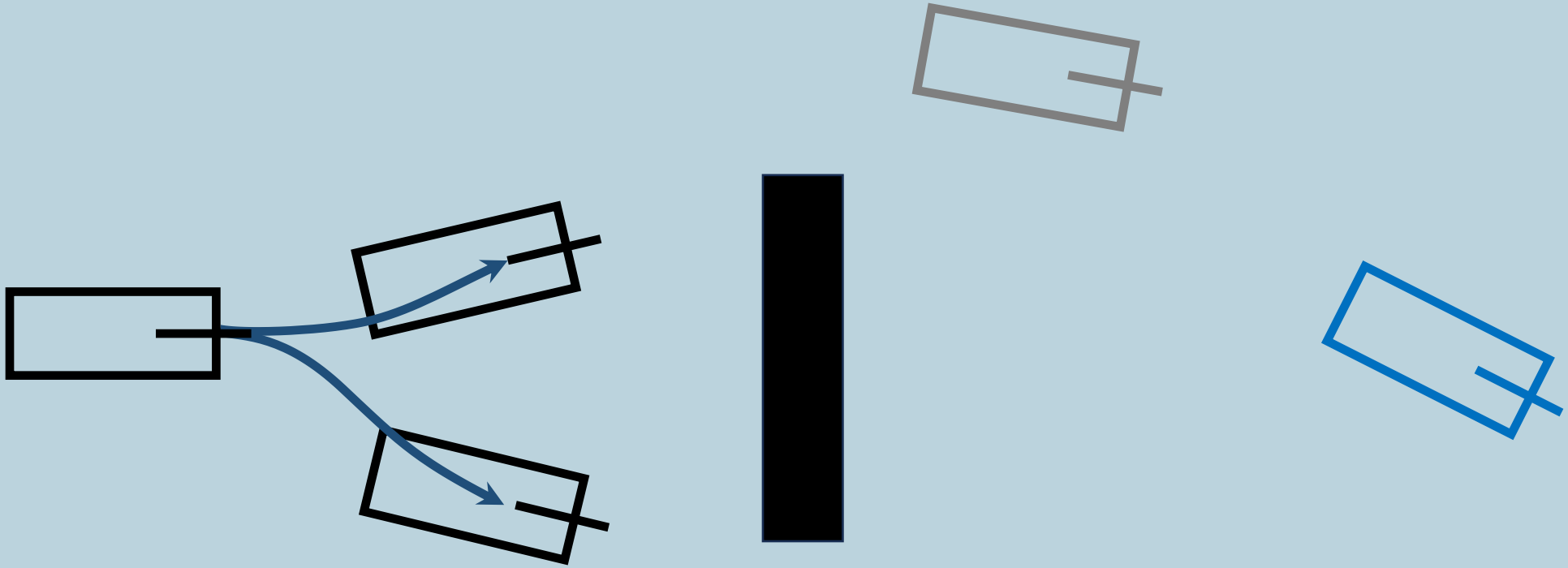
Repeat 1: Randomly sample a state



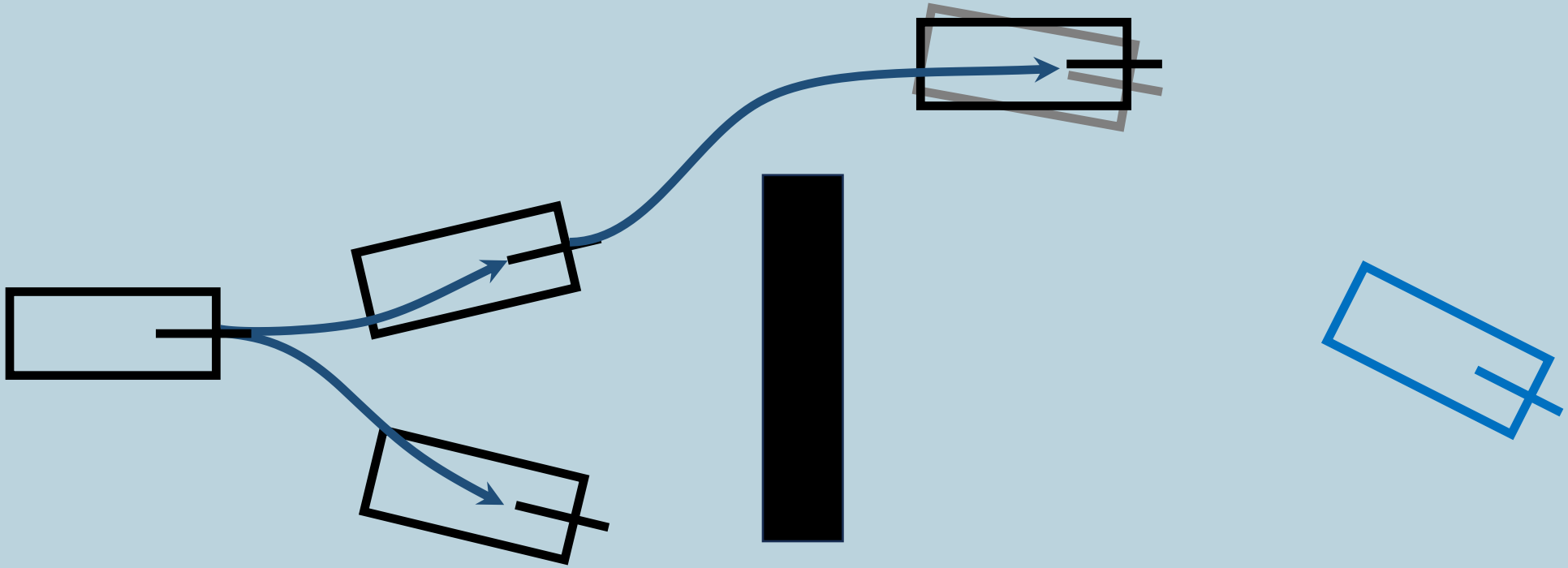
2. Try to get there from closest known pose



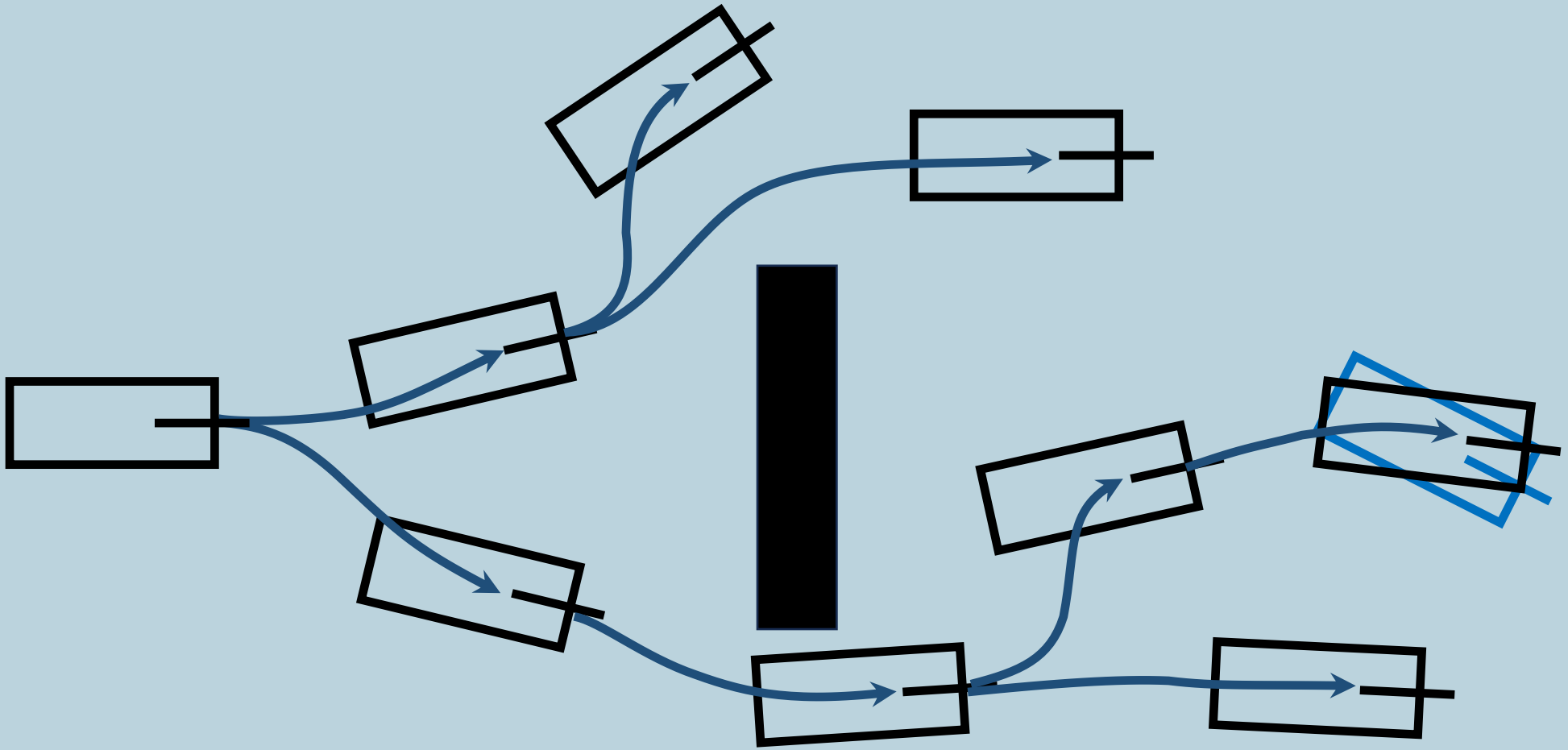
Repeat 1: Randomly sample a state



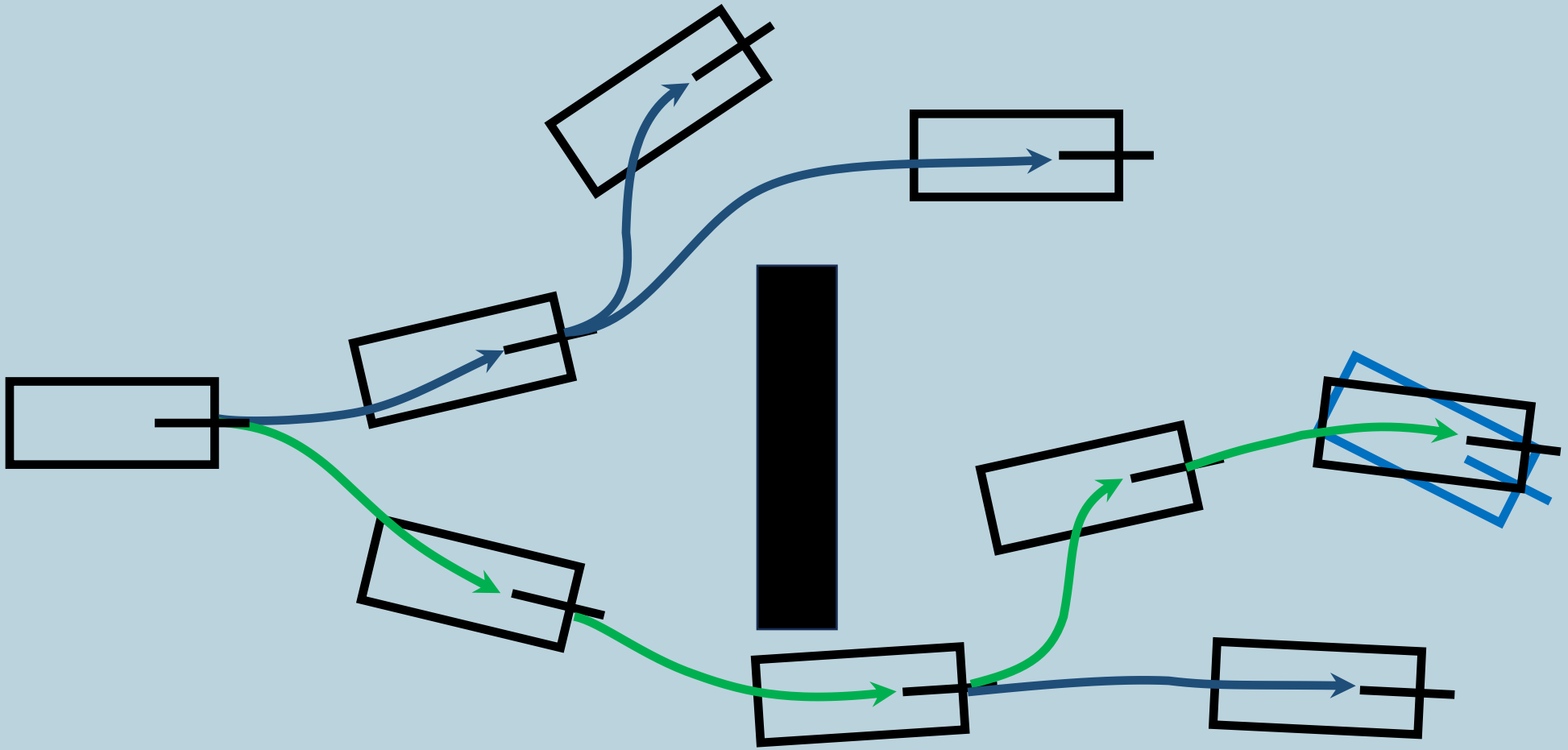
2. Try to get there from closest known pose

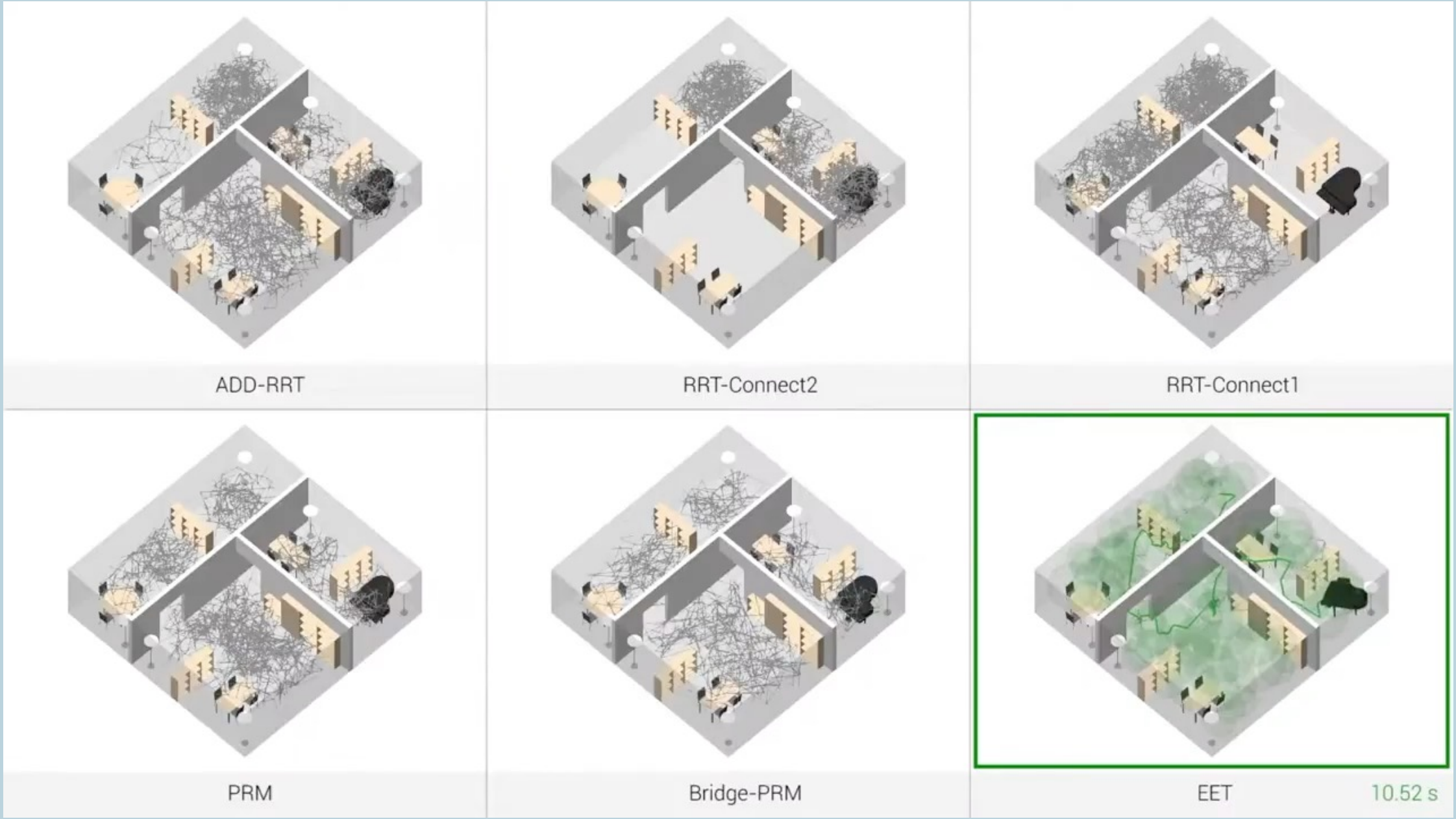


Repeat until goal reached



Extract plan by backtracking from goal to start





Liberal Arts development studio LAITS

Rickert, Markus, Arne Sieverling, and Oliver Brock. "Balancing exploration and exploitation in sampling-based motion planning." *IEEE Transactions on Robotics* 30.6 (2014): 1305-1317.

https://www.youtube.com/watch?v=HdfAzUXvmOQ

TEXAS

[Now in 2023]: So… Is ~~AI~~ Planning Solved?

Revision: The Planning Problem

Given:

1. An ***initial state*** of the world
2. A set of ***available actions***, their requirements, and their effects
3. A ***goal state***
4. [Optionally] ***Costs*** associated with each action

Compute:

A ***valid sequence of actions*** (the ***plan***) that starts from the initial state and terminates at the goal state [with fewest actions / minimum cost]

Active Areas Of Research In Planning

What if you don't know everything?
E.g., What's behind a box before pulling it

Given:

1. An ***initial state*** of the world
2. A set of ***available actions***, their requirements, and their effects
3. A ***goal state***
4. [Optionally] ***Costs*** associated with each action

Compute:

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Active Areas Of Research In Planning

Given:

1. An ***initial state*** of the world
2. A set of ***available actions***, their requirements, and their effects
3. A ***goal state***
4. [Optionally] ***Costs*** associated with each action

What if this is hard to predict?
E.g., Driving at high speed on ice

Compute:

A ***valid sequence of actions*** (the ***plan***) that starts from the initial state and terminates at the goal state [with fewest actions / minimum cost]

Active Areas Of Research In Planning

Given:

1. An ***initial state*** of the world
2. A set of ***available actions***, their requirements, and their effects
3. A ***goal state***
4. [Optionally] ***Costs*** associated with each action

What if this is ill-specified?

E.g., Plan an awesome hiking trip

Compute:

A ***valid sequence of actions*** (the ***plan***) that starts from the initial state and terminates at the goal state [with fewest actions / minimum cost]

Active Areas Of Research In Planning

Given:

1. An ***initial state*** of the world
2. A set of ***available actions***, their requirements, and their effects
3. A ***goal state***
4. [Optionally] ***Costs*** associated with each action

What if it is hard to specify?

E.g., Social costs of actions

Compute:

A ***valid sequence of actions*** (the ***plan***) that starts from the initial state and terminates at the goal state [with fewest actions / minimum cost]

Summary

- The planning problem
- Three applications of planning
  - Symbolic planning
  - Adversarial planning
  - Motion planning
- Three approaches to planning
  - Search + heuristics
  - Adversarial search + heuristics + learning
  - Rapidly Exploring Random Trees
- Open research problems in planning