Practical Model Predictive Control

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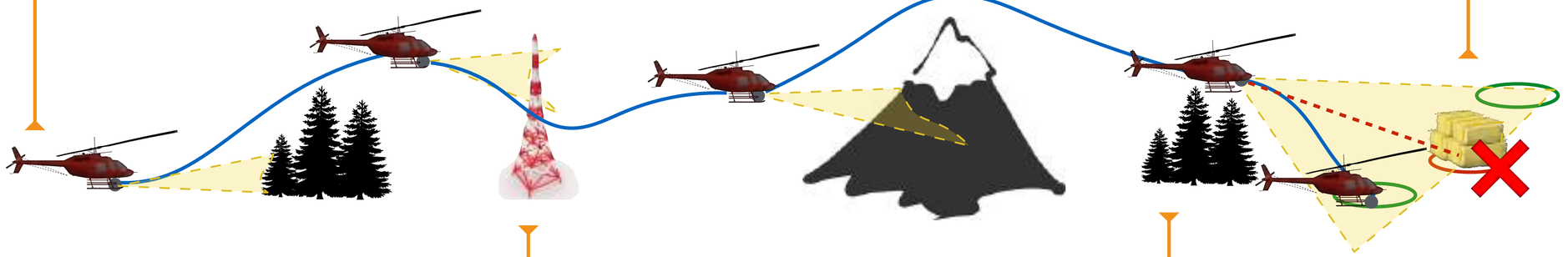
Congratulate yourself!

- ✓ Analytically solve continuous state action MDP (LQR)
- ✓ Handle non-linear costs, dynamics (iLQR)
- ✓ Handle constraints (AuLa)

Today's plan: Let's interact (a lot!)


Nirvana!
Partial Observability
Non-convexity
Long Horizons

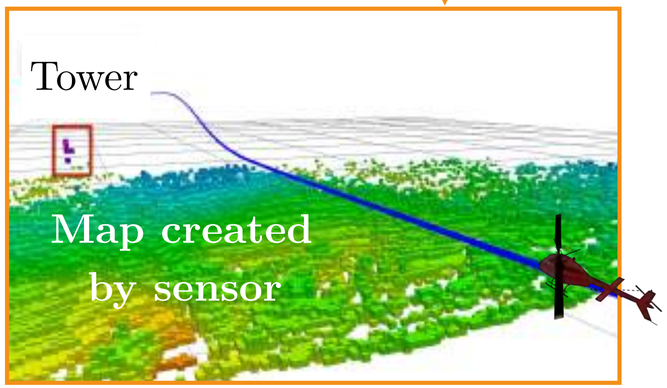

Nirvana!
Long Horizons

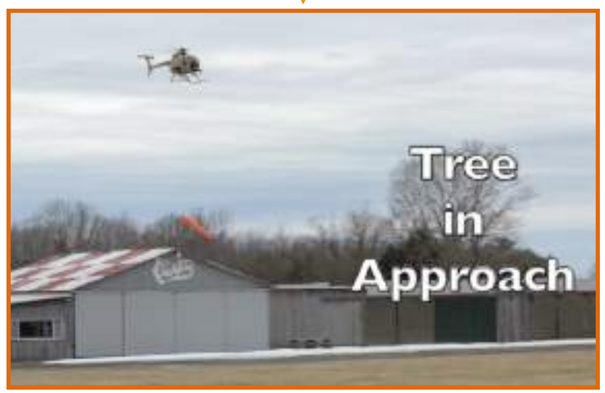


Takeoff
(Respect power constraints)

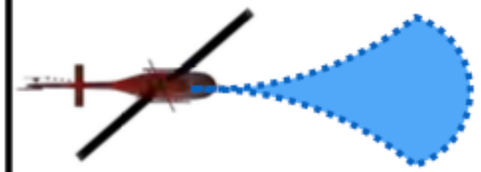
Enroute
(Avoid sensed obstacles)

Touchdown
(Plan to multiple sites)





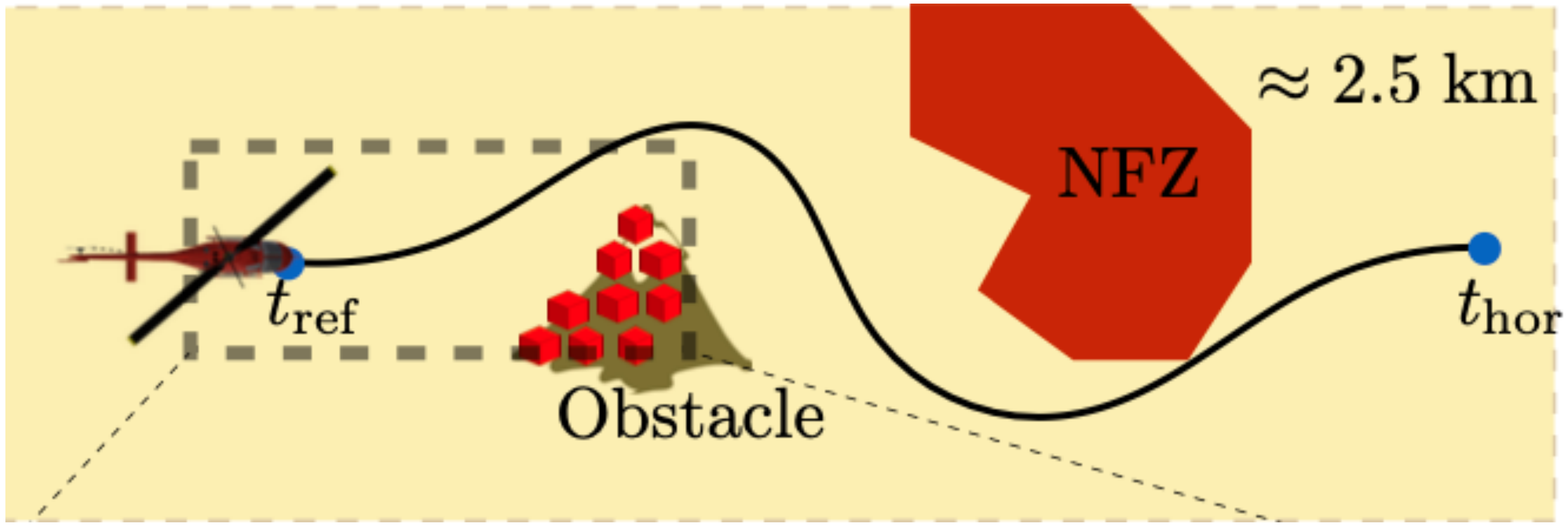
Can apply iLQR!



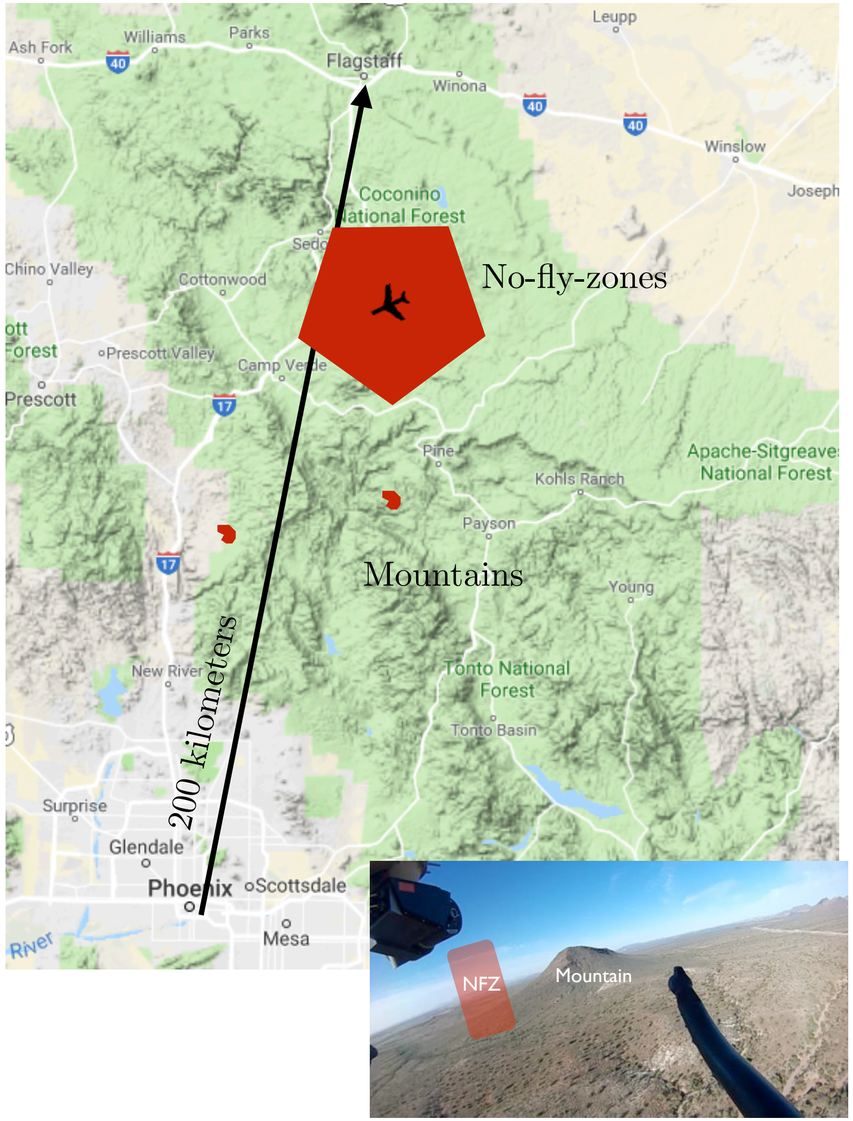
$$s = (x, y, z, \psi, \dot{x}, \dot{y}, \dot{z}, \dot{\psi}, \ddot{x}, \ddot{y}, \ddot{z}, \ddot{\psi})$$

$$\mathcal{F}_{\text{dyn}}(\sigma) = 0$$

$$\mathcal{H}_{\text{dyn}}(\sigma) \leq 0$$



Problem: How do we plan 200 km?



Example mission:

Fly from Phoenix to Flagstaff as fast as possible (200 km)

Problem:

Take forever to plan at high resolution ALL the way to goal

Activity!

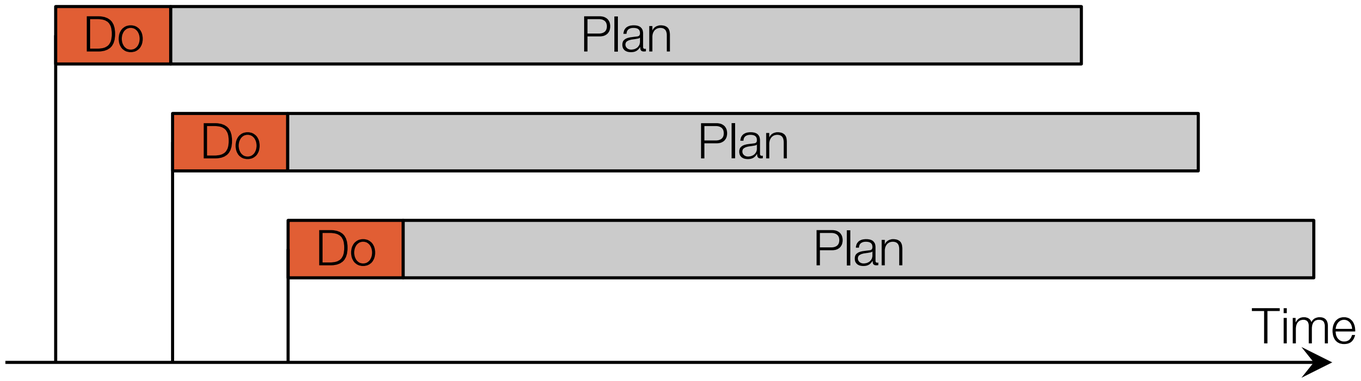
Think-Pair-Share

Think (30 sec): How do we plan in real-time for a helicopter to go from A to B that is really really far apart?

Pair: Find a partner

Share (45 sec): Partners exchange ideas

Receding Horizon Control (also called MPC!)

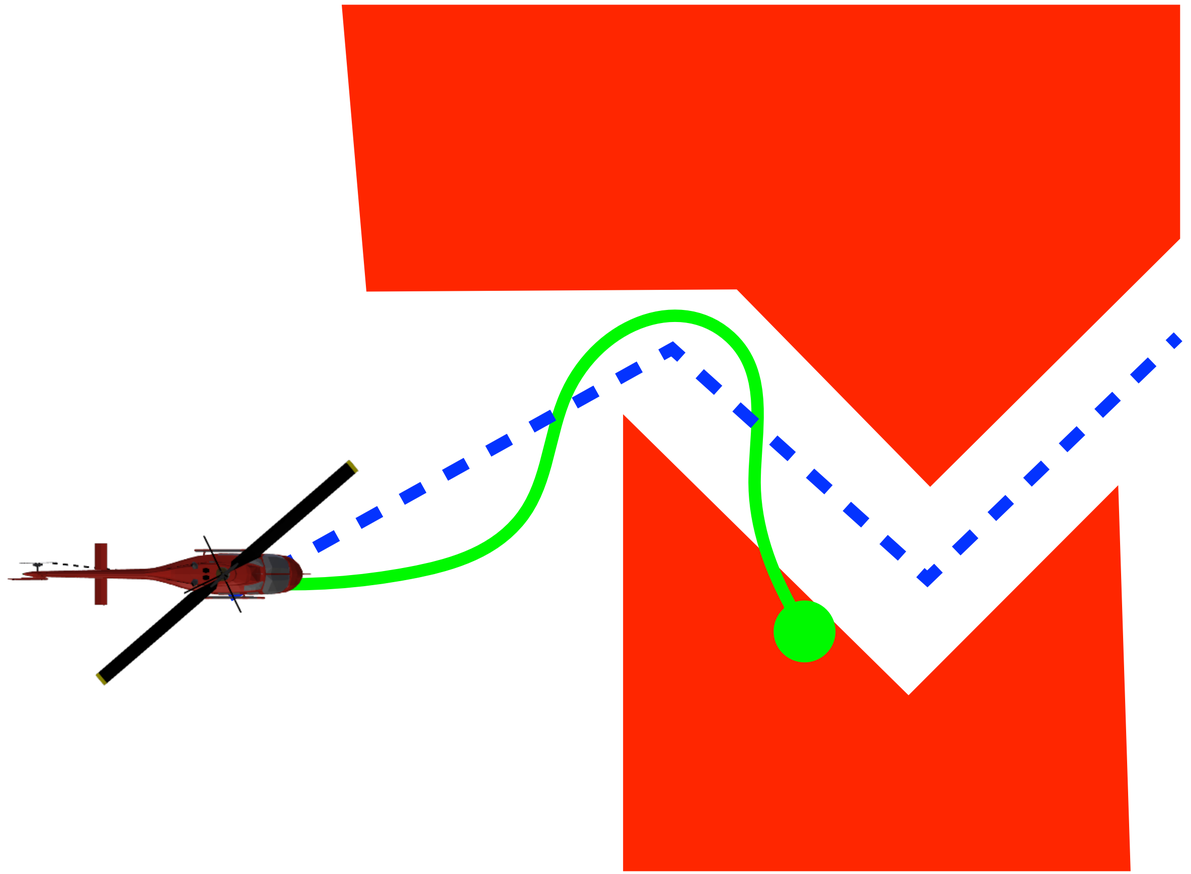


Step 1: Solve optimization problem to a horizon

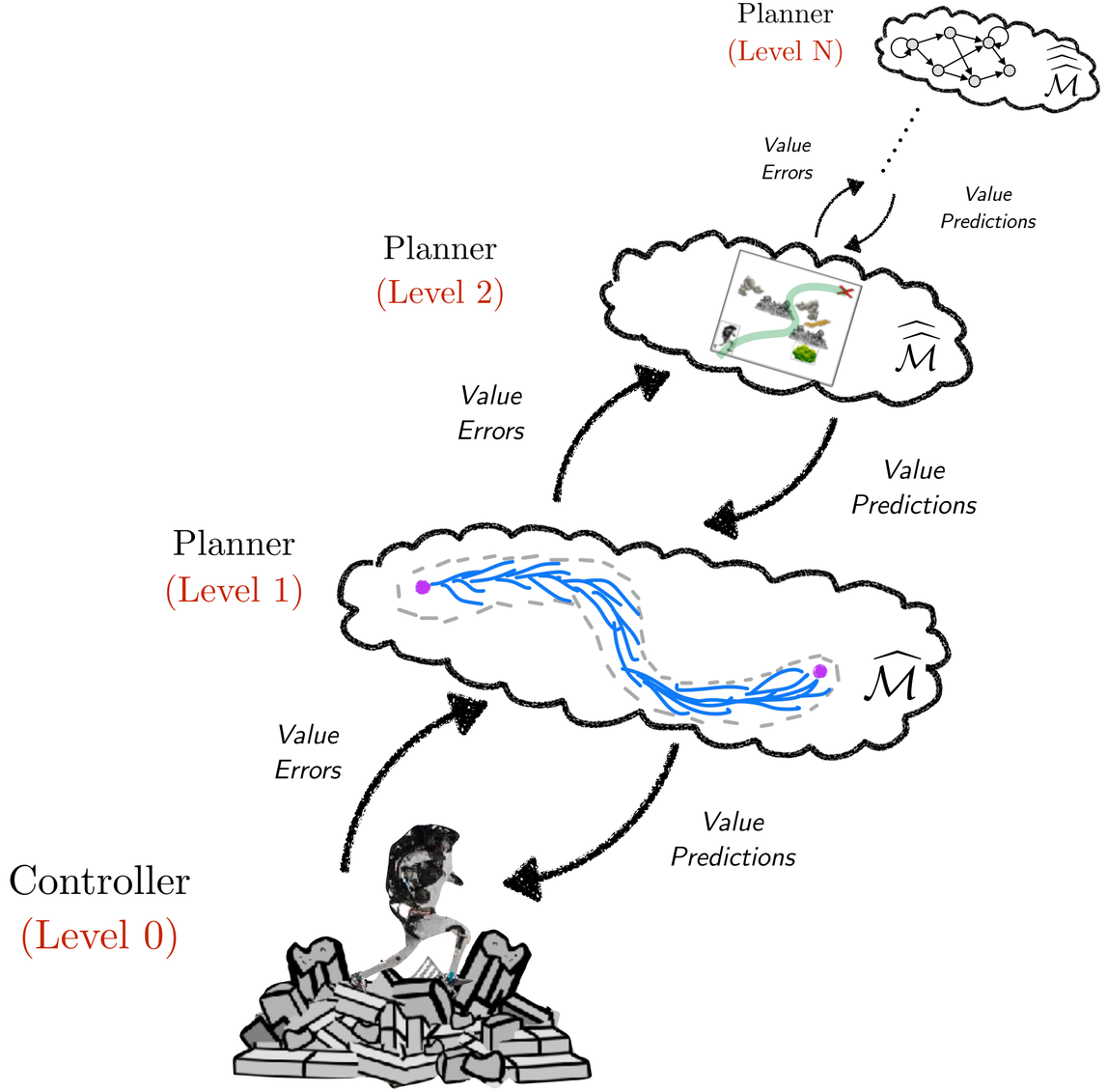
Step 2: Execute the first control

Step 3: Repeat!

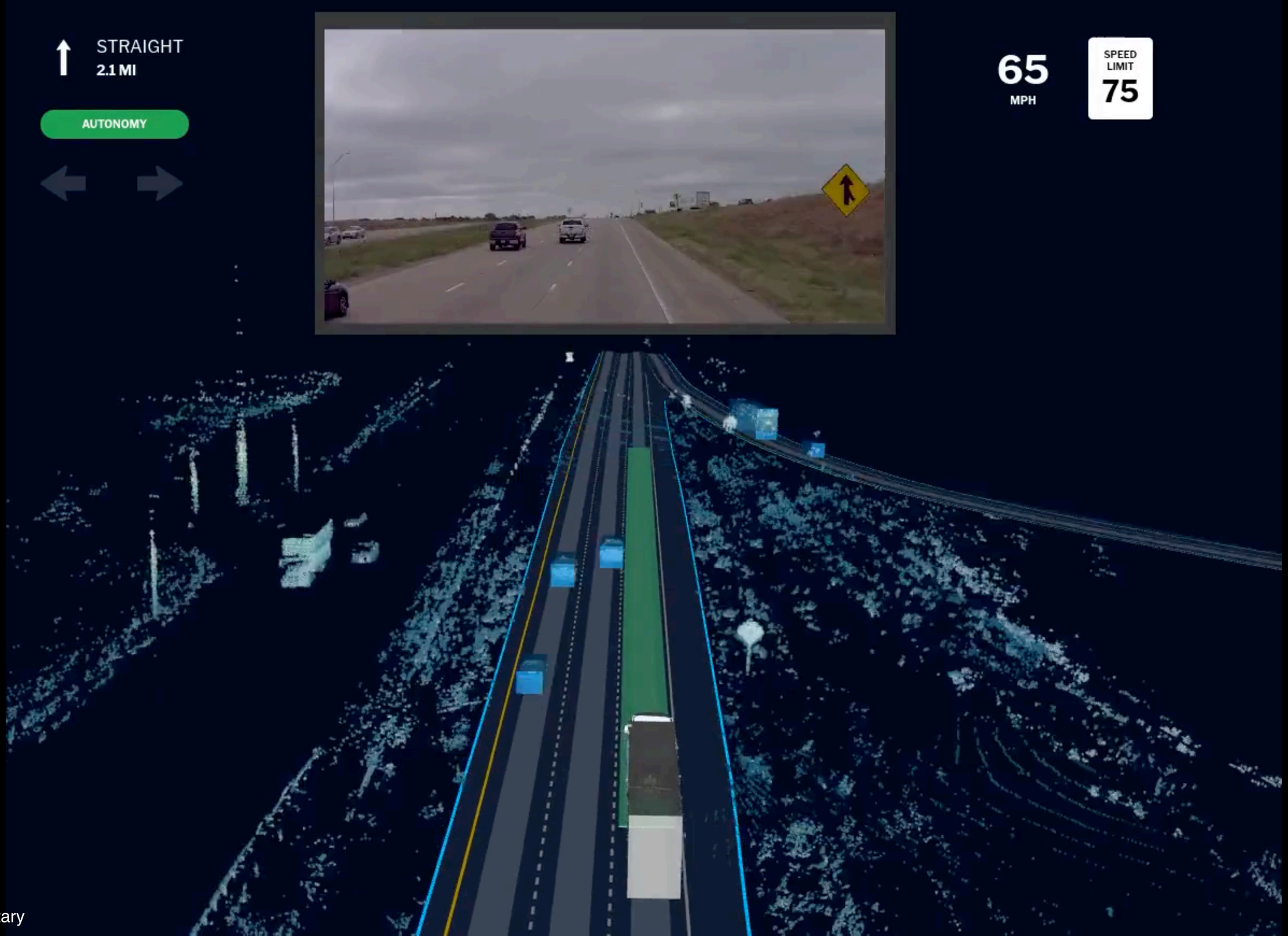
Problem: What happens when your global path is impossible to track?

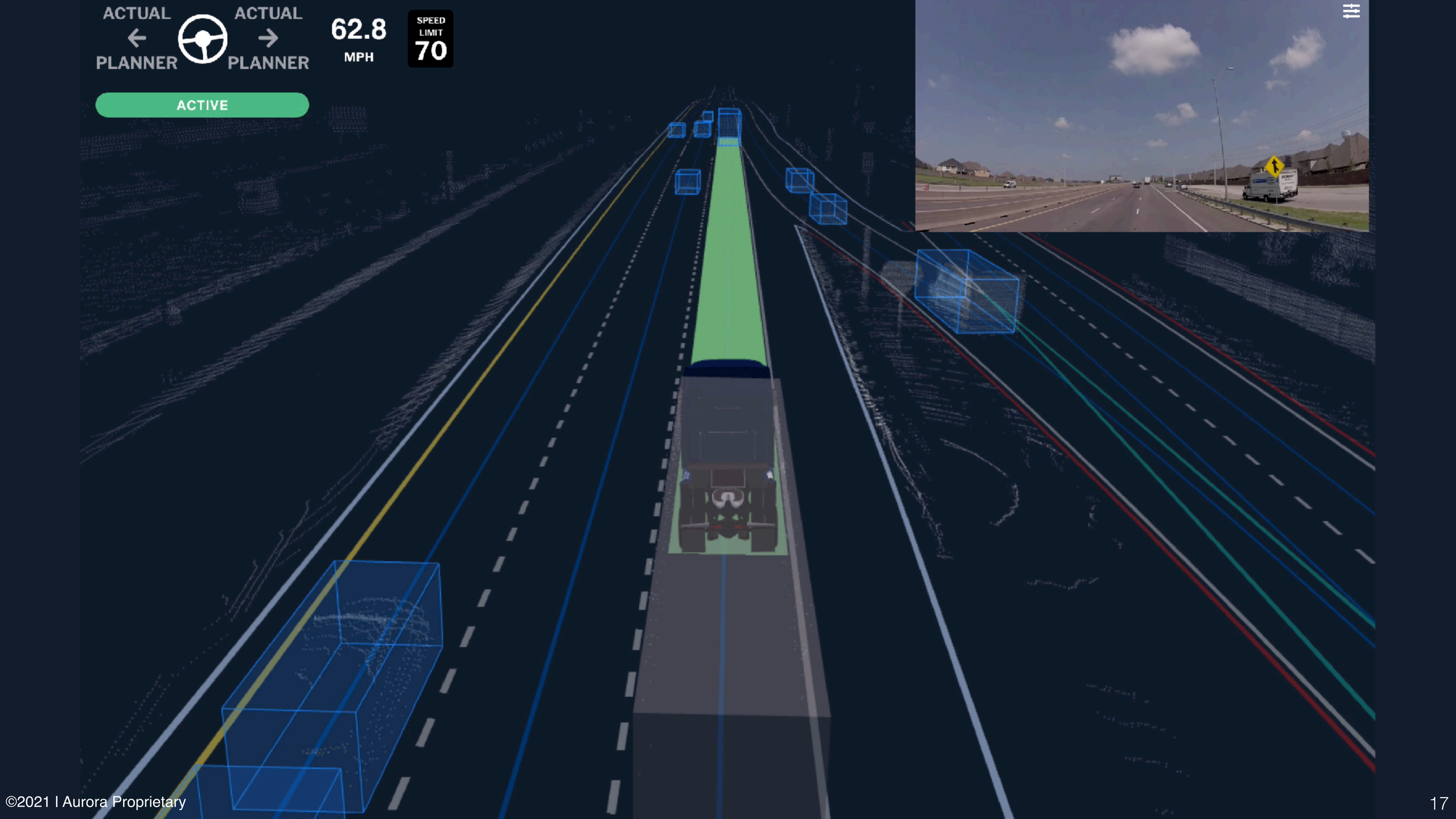


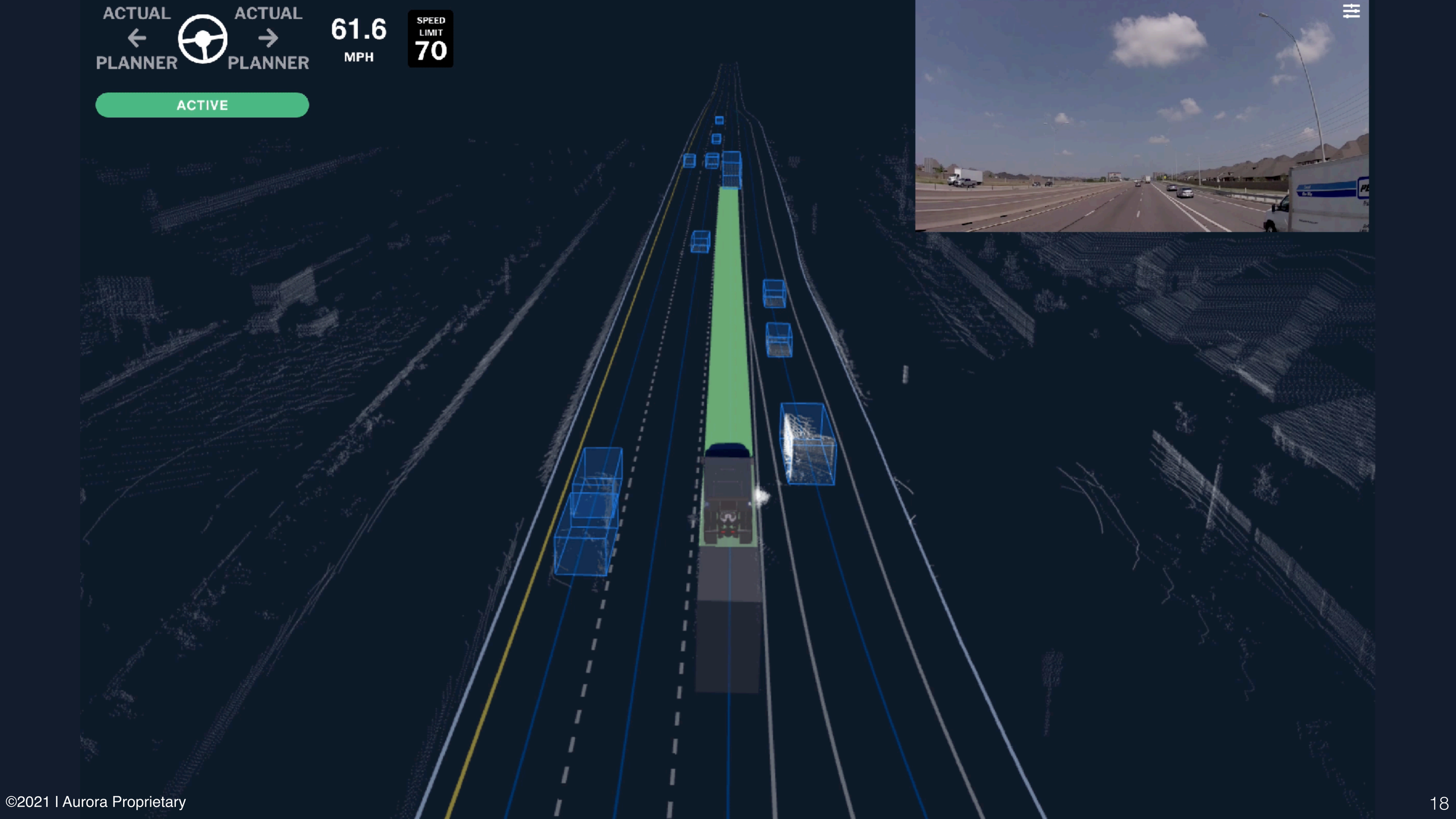
Hierarchy of value functions




Nirvana!
Non-convexity







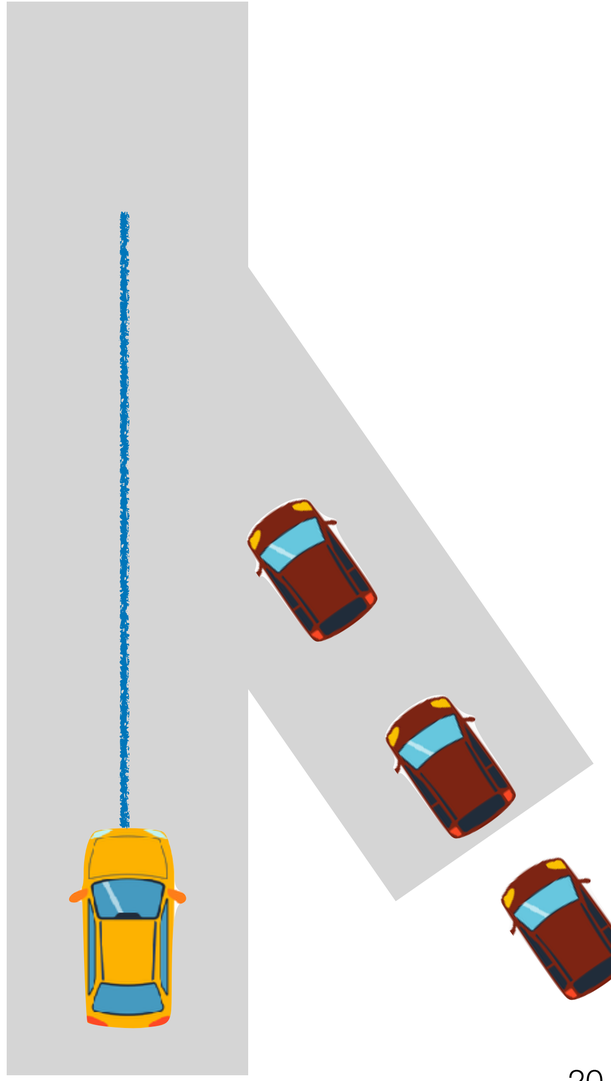
Activity!

Think-Pair-Share

Think (30 sec): How will you get iLQR to find the best plan to merge between multiple cars?

Pair: Find a partner

Share (45 sec): Partners exchange ideas



Ways to initialize iLQR

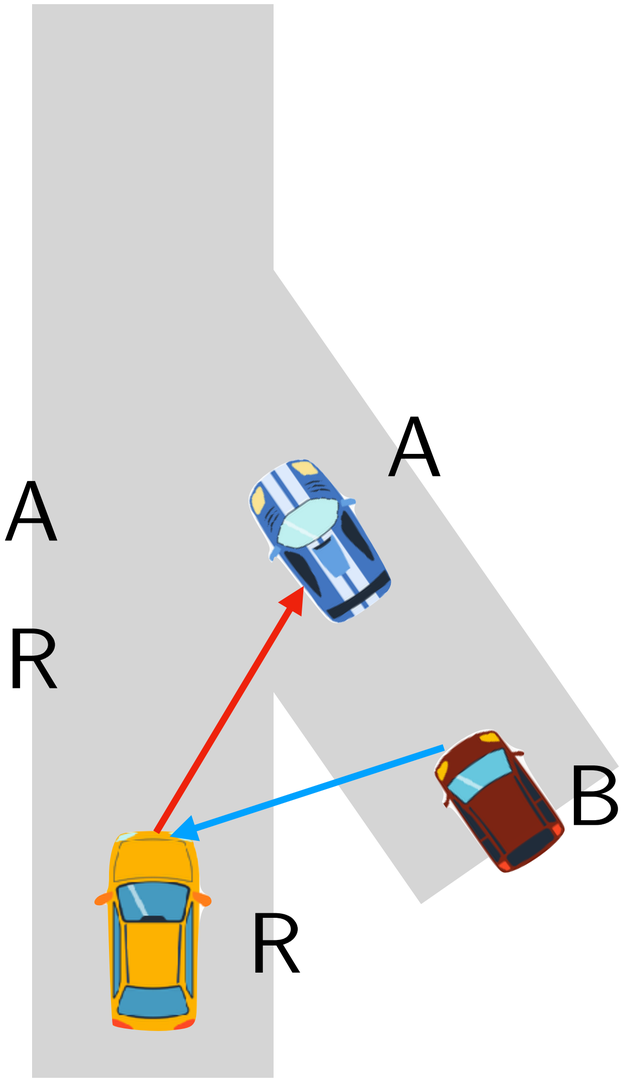
Try multiple random seeds

Try to find discrete modes

Mode ≡ A single basin of solution

R Yields to A

B Yields to R



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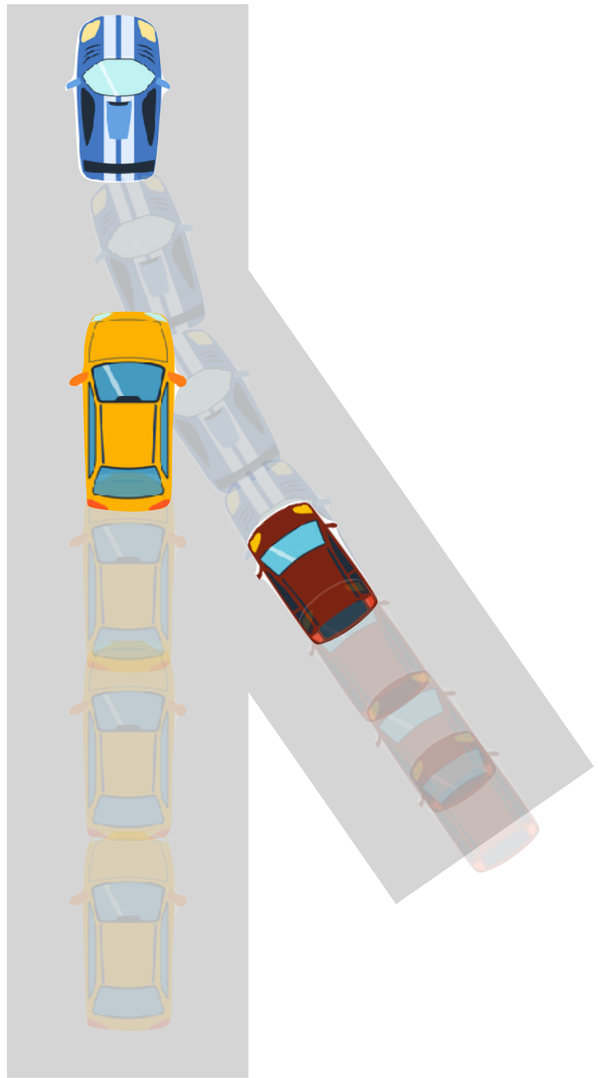
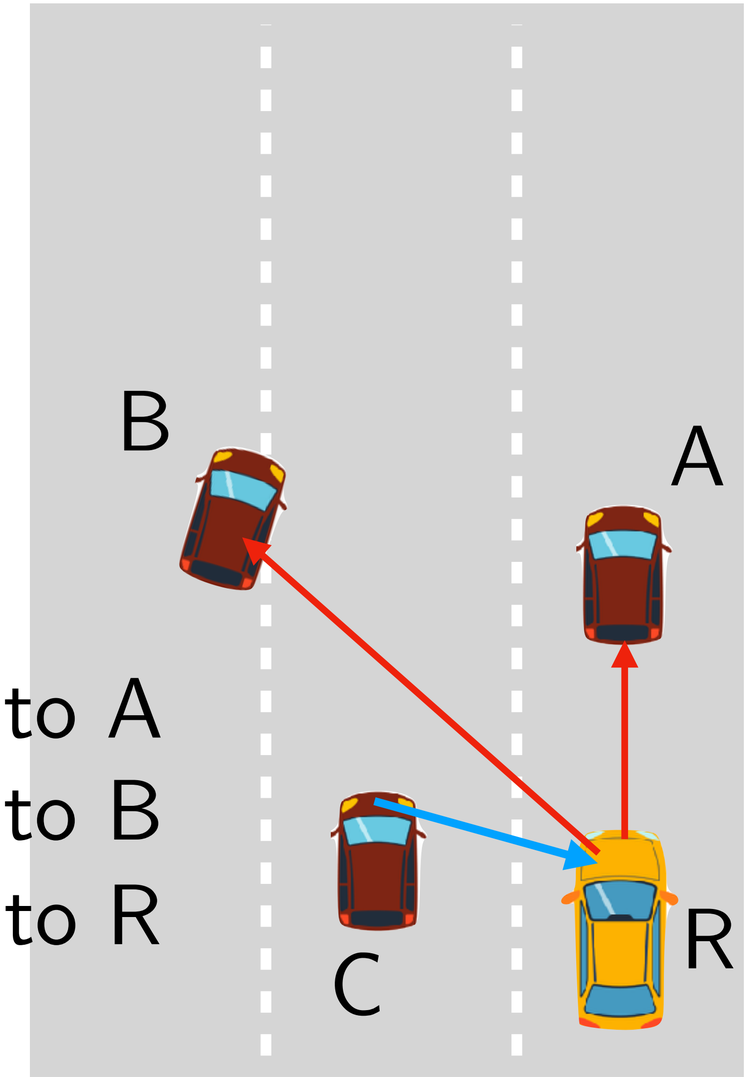
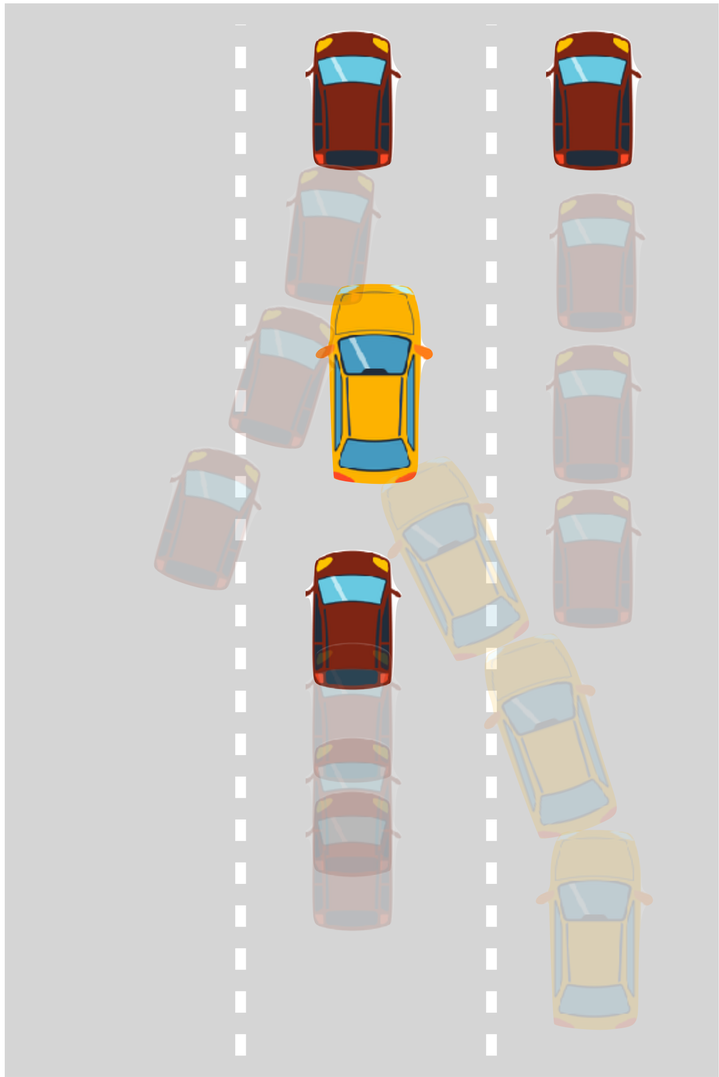


Mode ≡ A single basin of solution



R Yields to A
R Yields to B
C Yields to R

≡

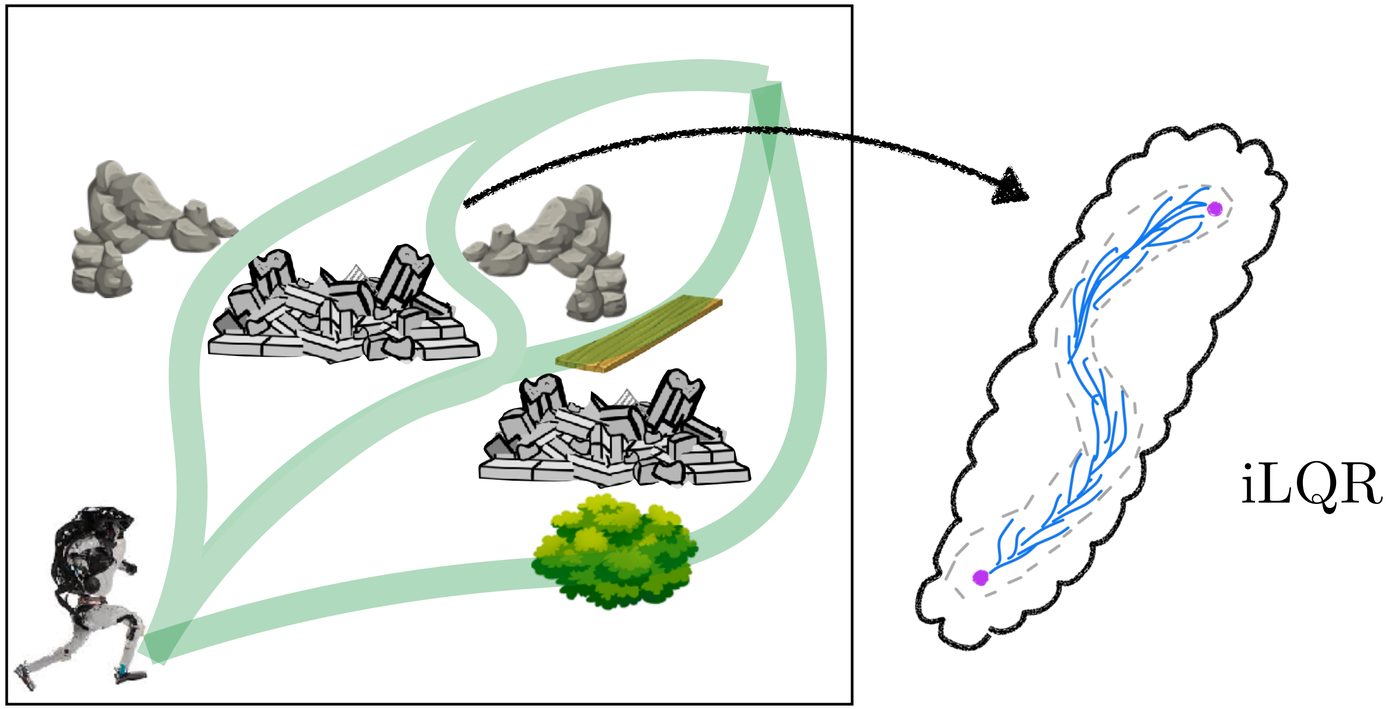


How do you find modes for this .... ?

Train a learner to predict modes

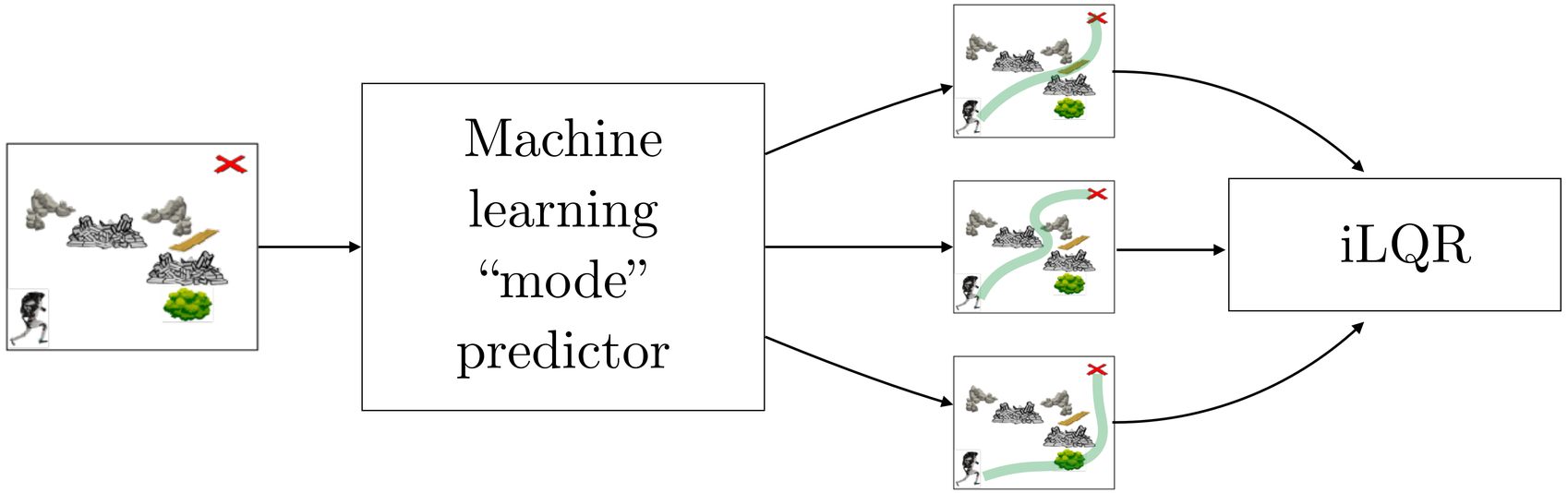
mode: a single basin of solution, e.g. workspace tube, sequence of phases, symbols, etc

[Toussiant'18], [Deits&Tedrake'15], [Mordatch etal'12]



iLQR

Train a learner to predict modes



Can be formulated as a list-prediction problem!

Dey, D., Liu, T. Y., Hebert, M., & Bagnell, J. A. (2013). Contextual sequence prediction with application to control library optimization. Proceedings of robotics: Science and systems VIII.

Nirvana!

Partial Observability

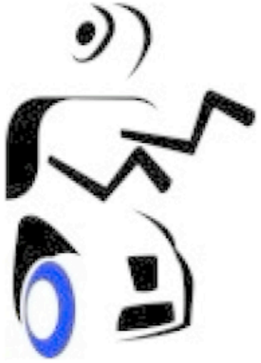
The Blindfolded Robot: A Bayesian Approach to Planning with Contact Feedback

An overview of experiments

Brad Saund, Sanjiban Choudhury, Siddhartha Srinivasa, Dmitry Berenson

M ROBOTICS

ARM LAB
AUTONOMOUS ROBOTIC MANIPULATION



Partially Observable Markov Decision Process (POMDP)

NP-Hard at best

Undecidable in some cases

We will have a whole lecture on how to get around solving POMDPs!