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!)
Long Horizons
Non-convexity
Partial Observability
Nirvana!
Long Horizons

Nirvana!
Takeoff
(Respect power constraints)

Enroute
(Avoid sensed obstacles)

Touchdown
(Plan to multiple sites)
Can apply iLQR!

\[ s = (x, y, z, \psi, \dot{x}, \dot{y}, \dot{z}, \dot{\psi} ) \]

\[ F_{\text{dyn}}(\sigma) = 0 \]

\[ H_{\text{dyn}}(\sigma) \leq 0 \]
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

Planner (Level N)

Planner (Level 2)

Planner (Level 1)

Controller (Level 0)
Non-convexity

Nirvana!
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 $\equiv$ A single basin of solution

R Yields to A
B Yields to R
Mode $\equiv$ 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]
Train a learner to predict modes

Can be formulated as a list-prediction problem!

Partial Observability

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

An overview of experiments

Brad Saund, Sanjiban Choudhury, Siddhartha Srinivasa, Dmitry Berenson
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!