CSE 571
Inverse Optimal Control
(Inverse Reinforcement Learning)

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Carnegie Mellon University

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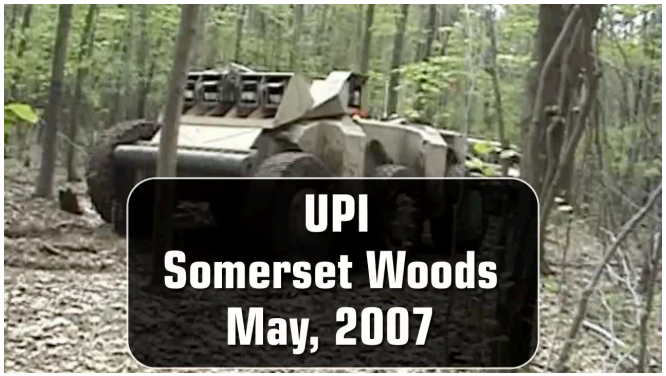
Autonomous Navigation



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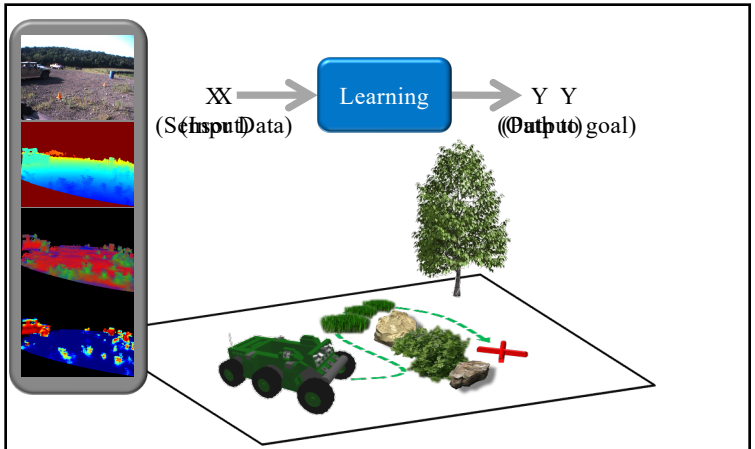

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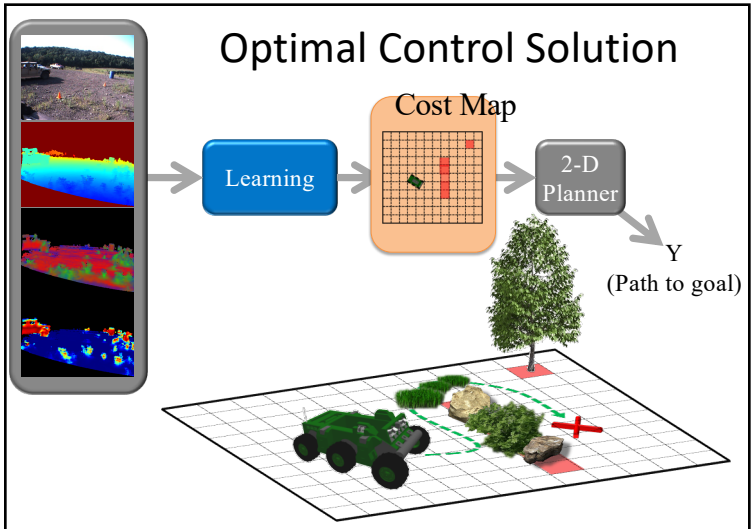
Optimal Control Solution



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Mode 1: Training example

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Mode 1: Training example

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Mode 1: Learned behavior

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Mode 1: Learned behavior

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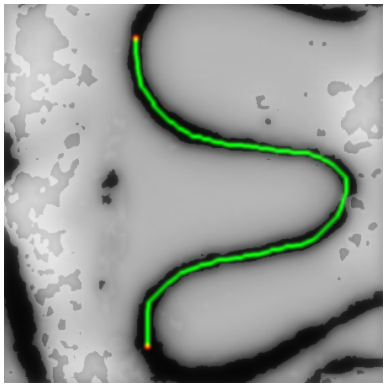
Mode 1: Learned cost map



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Mode 2: Training example

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Mode 2: Training example

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Mode 2: Learned behavior

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Mode 2: Learned behavior

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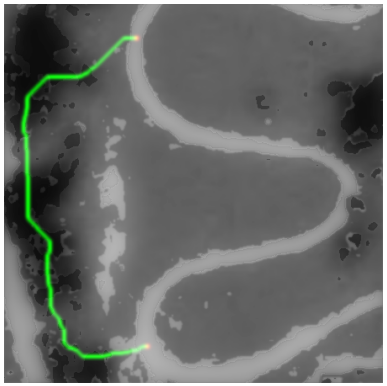
Mode 2: Learned cost map



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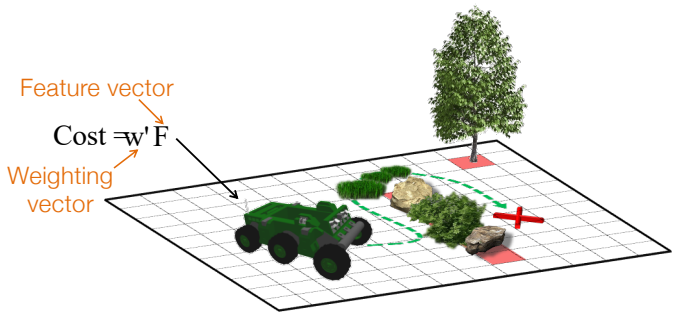

Ratliff, Bagnell, Zinkevich 2005
Ratliff, Bradley, Bagnell, Chestnutt, NIPS 2006
Silver, Bagnell, Stentz, RSS 2008

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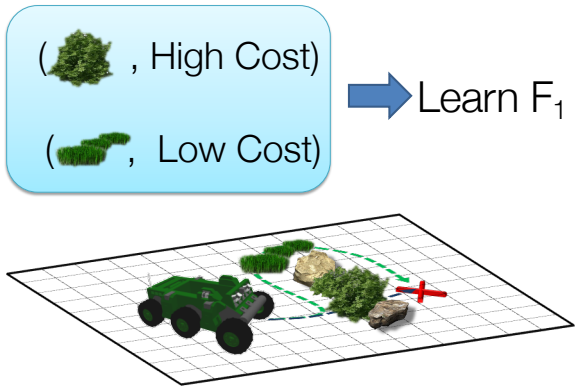

Ratliff, Bagnell, Zinkevich, ICML 2006
Ratliff, Bradley, Bagnell, Chestnutt, NIPS 2006
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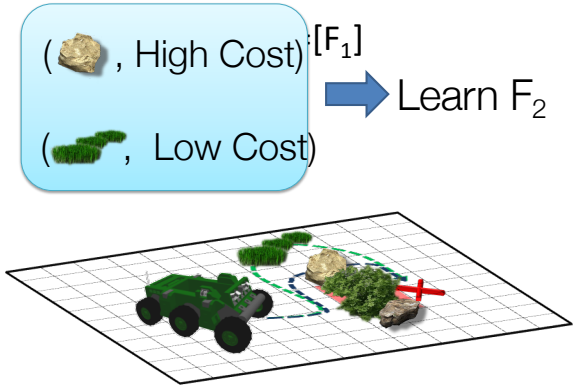

Ratliff, Bagnell, Zinkevich, ICML 2006
Ratliff, Bradley, Bagnell, Chestnutt, NIPS 2006
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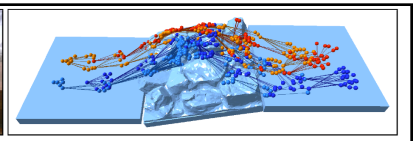


Ratliff, Bradley, Chesnutt, Bagnell 06

Zucker, Ratliff, Stolle, Chesnutt, Bagnell, Atkeson, Kuffner 09

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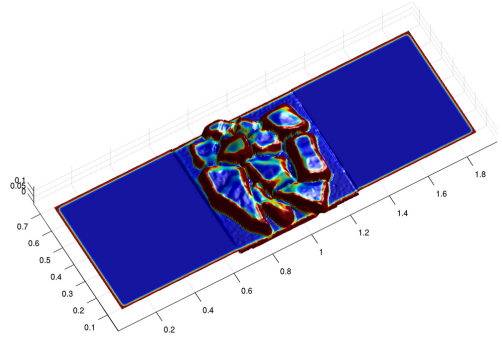
Learned Cost Function Examples



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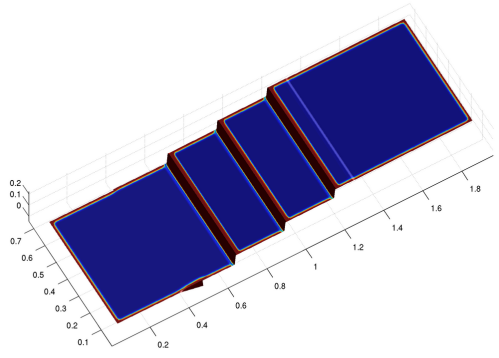
Learned Cost Function Examples



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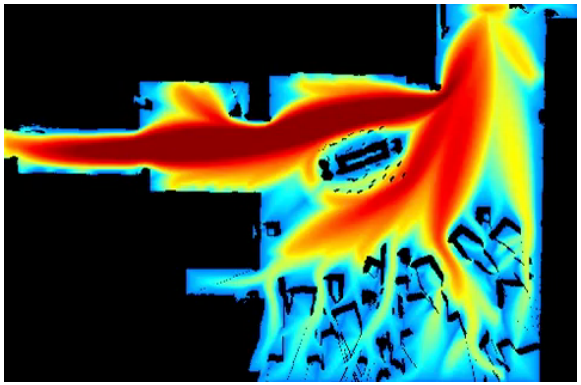
Pedestrian Trajectory Prediction



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Staying out of People's Path

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Learning Manipulation Preferences

- ***Input:*** Human demonstrations of preferred behavior (e.g., moving a cup of water upright without spilling)
- ***Output:*** Learned cost function that results in trajectories satisfying user preferences

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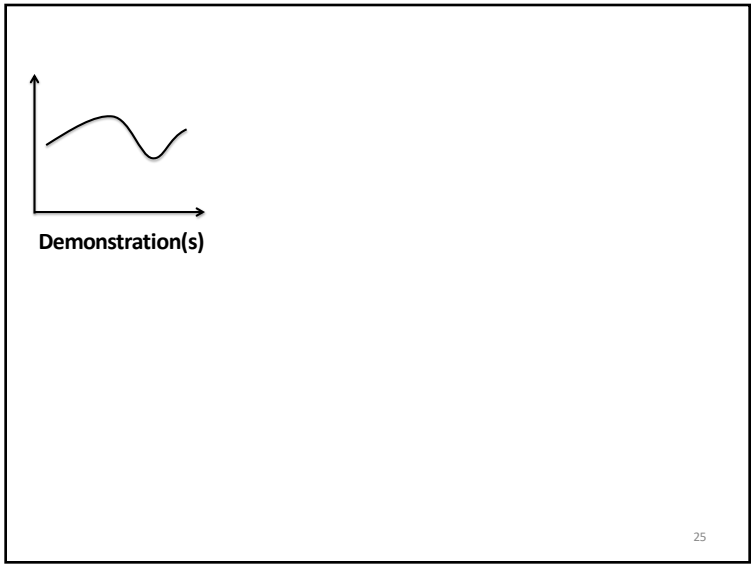
Demonstration(s)
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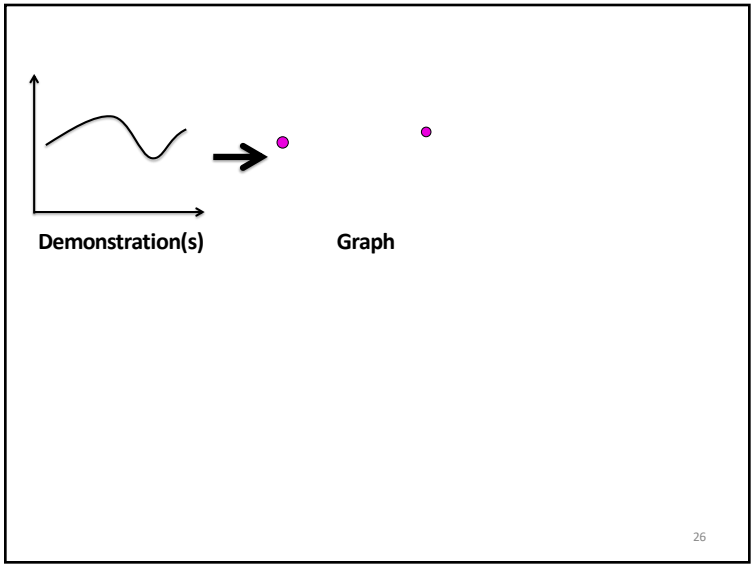
Demonstration(s)
Graph
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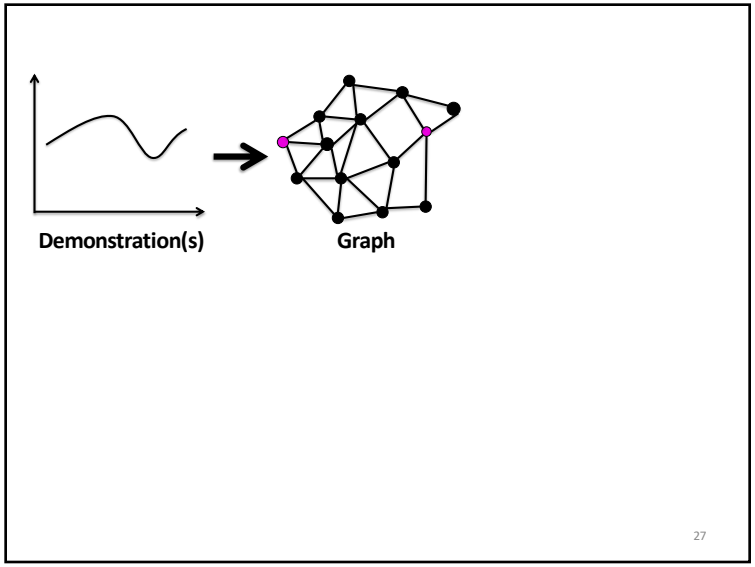
Demonstration(s)
Graph
27

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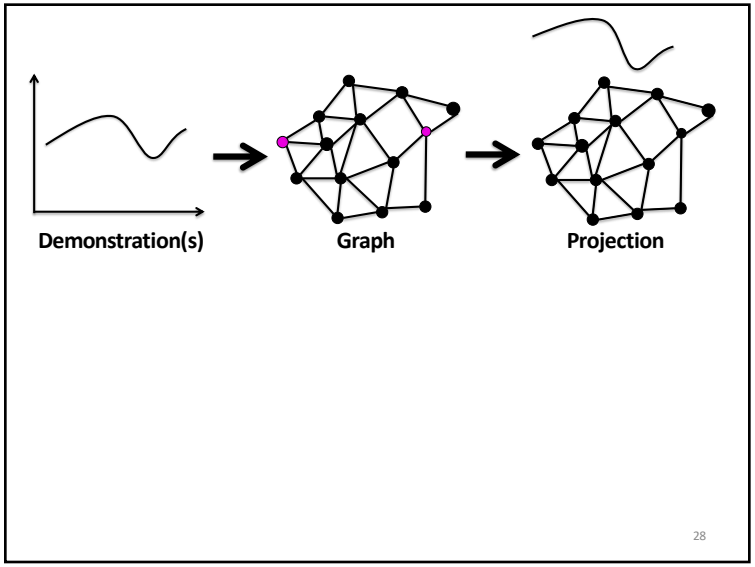
Demonstration(s)
Graph
Projection
28

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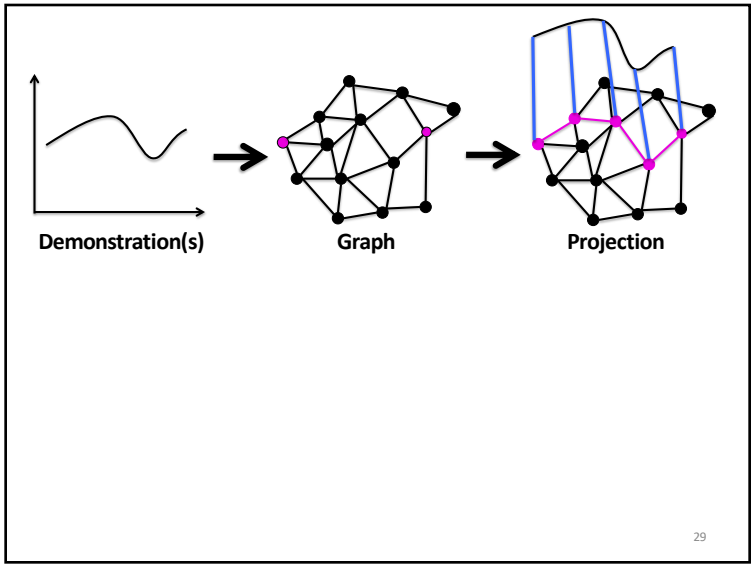
Demonstration(s)
Graph
Projection
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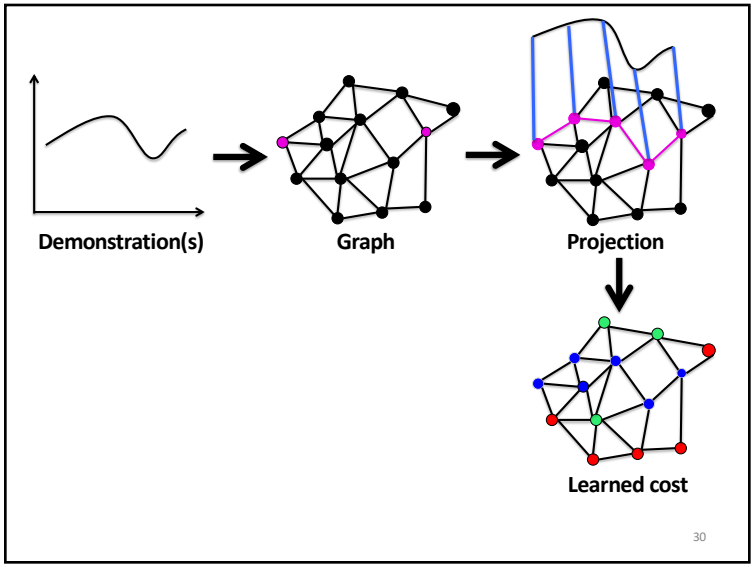
Demonstration(s)
Graph
Projection
Learned cost
30

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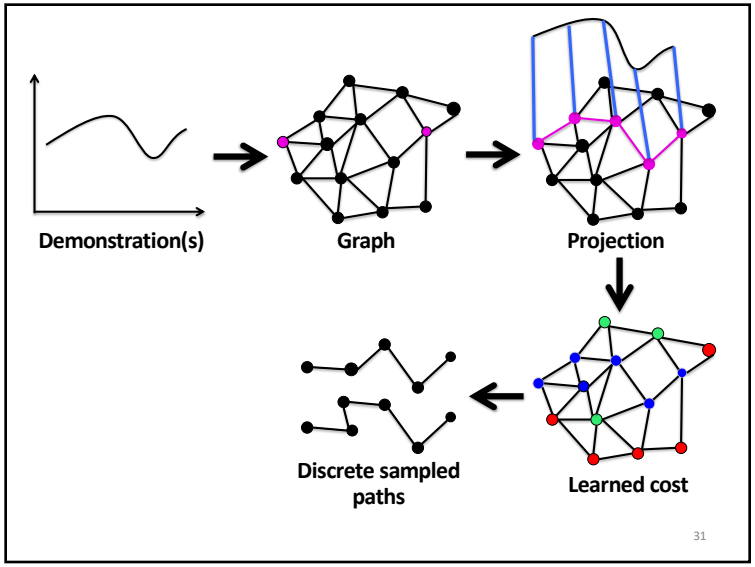
Demonstration(s)
Graph
Projection
Discrete sampled paths
Learned cost
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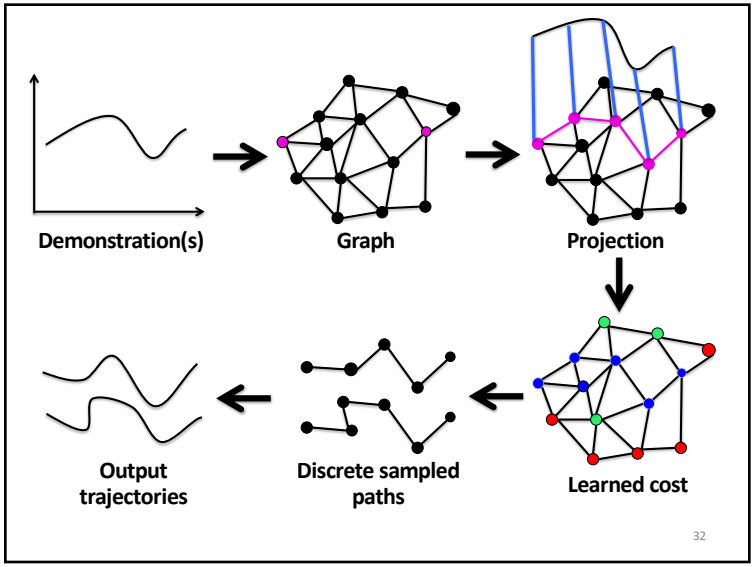
Demonstration(s)
Graph
Projection
Output trajectories
Discrete sampled paths
Learned cost
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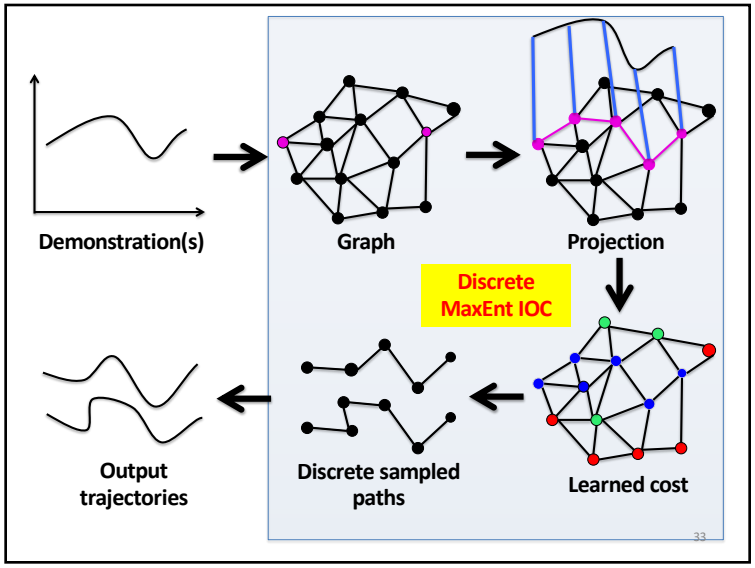

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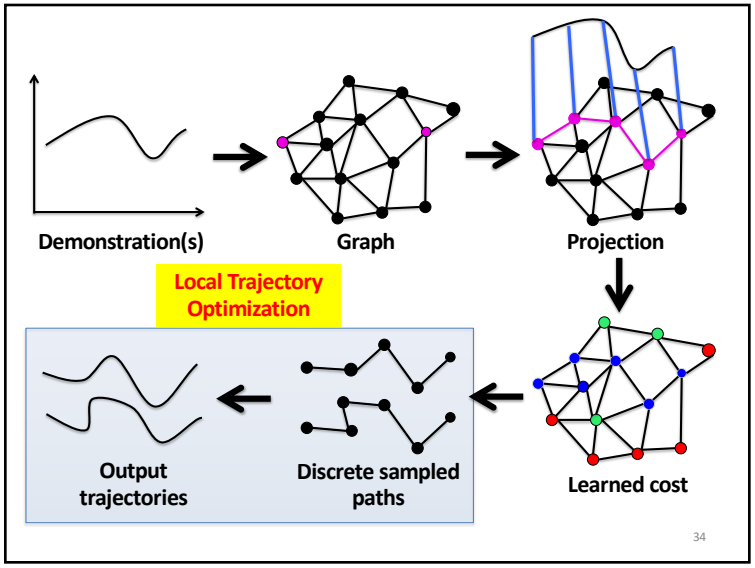

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Setup

- ***Binary*** state-dependent features (~95)
  - Histograms of distances to objects
  - Histograms of end-effector orientation
  - Object specific features (electronic vs non-electronic)
  - Approach direction w.r.t goal
- **Task**
  - Hold cup upright while not moving above electronics

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Laptop task: Demonstration

(Not part of training set)

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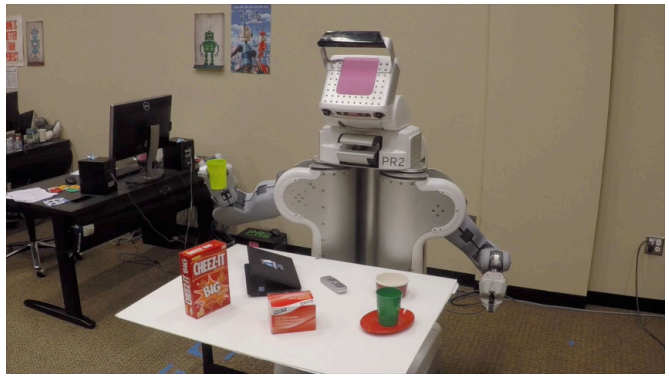
Laptop task: LTO + Discrete graph path



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Laptop task: LTO + Smooth random path

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Readings

- Max-Ent IRL (Ziebart, Bagnell): http://www.cs.cmu.edu/~bziebart/
- CIOC (Levine) http://graphics.stanford.edu/projects/cioc/cioc.pdf
- Manipulation (Byravan/Fox): https://rse-lab.cs.washington.edu/papers/graph-based-IOC-ijcai-2015.pdf
- Imitation learning (Ermon): https://cs.stanford.edu/~ermon/
- Human/manipulation (Dragan): https://people.eecs.berkeley.edu/~anca/research.html

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