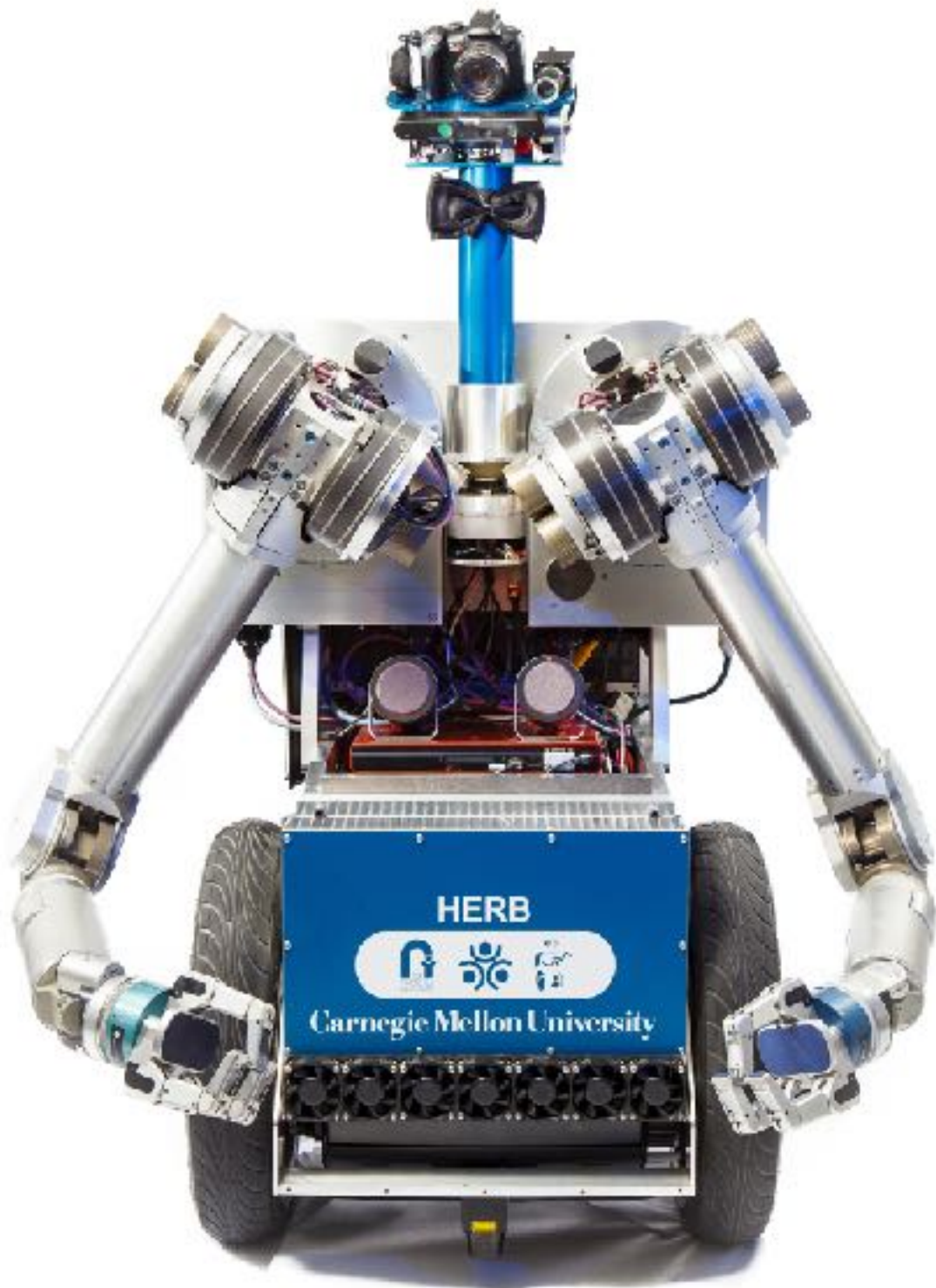


Manipulation under Uncertainty

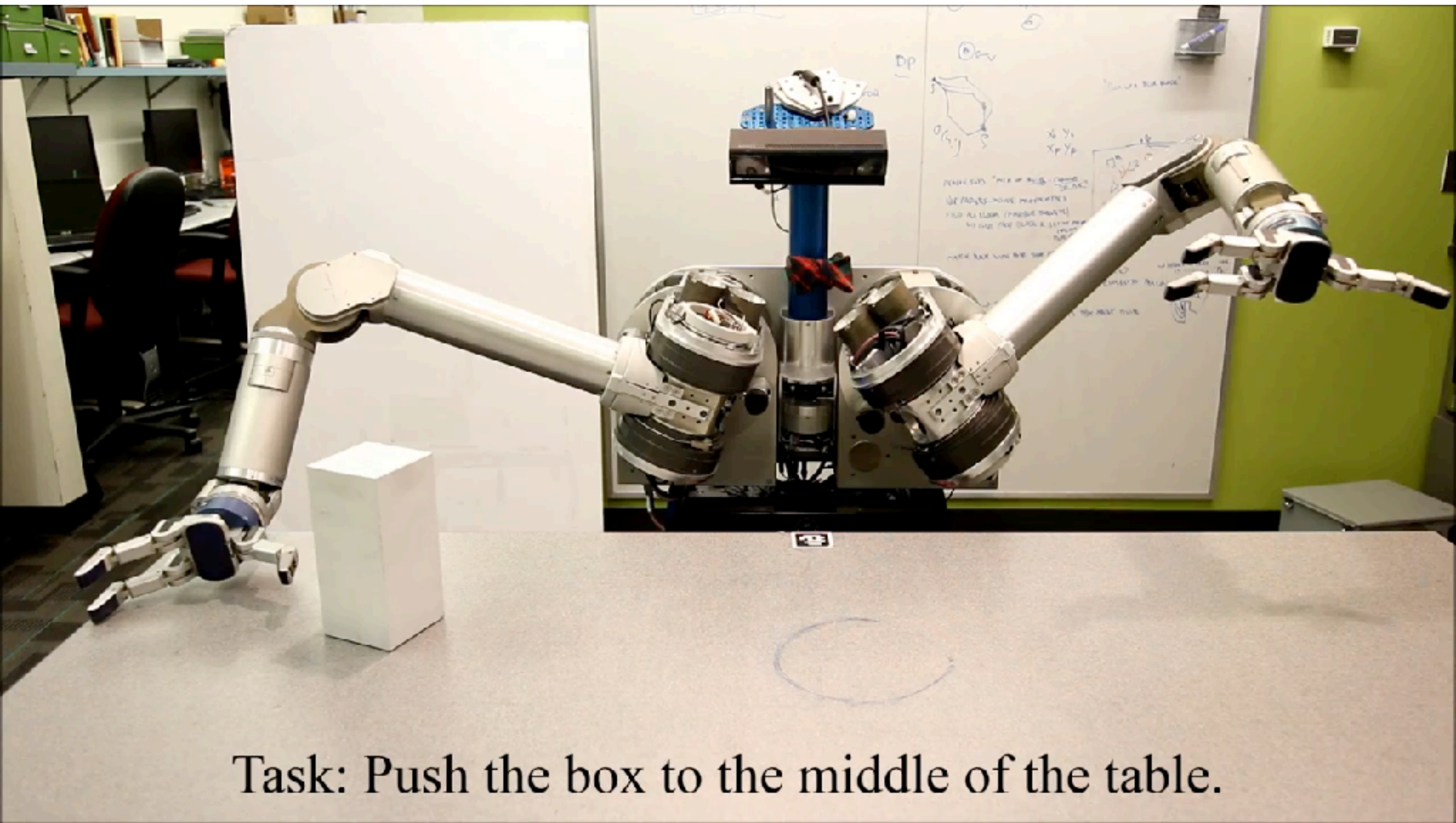


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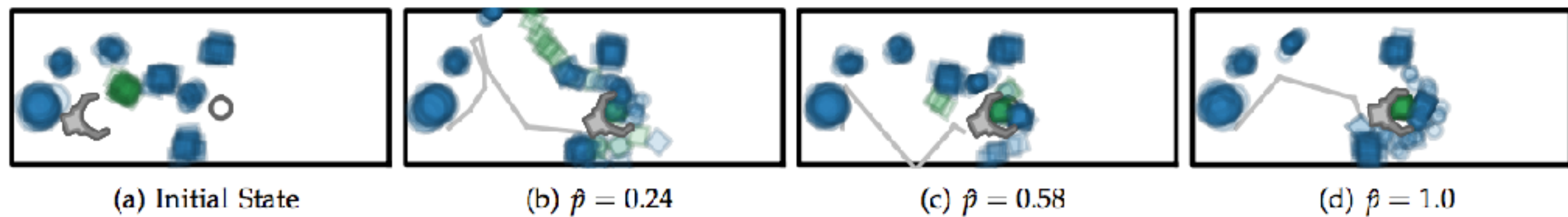
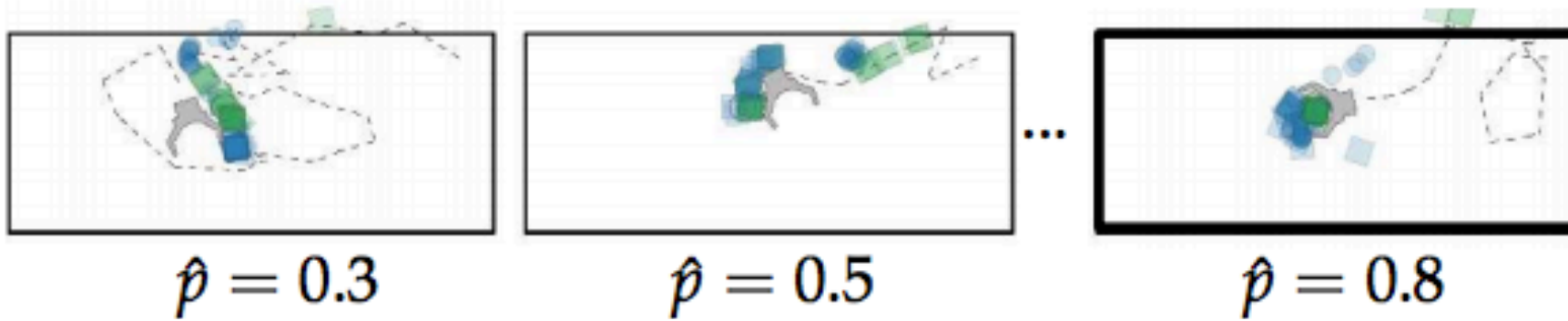
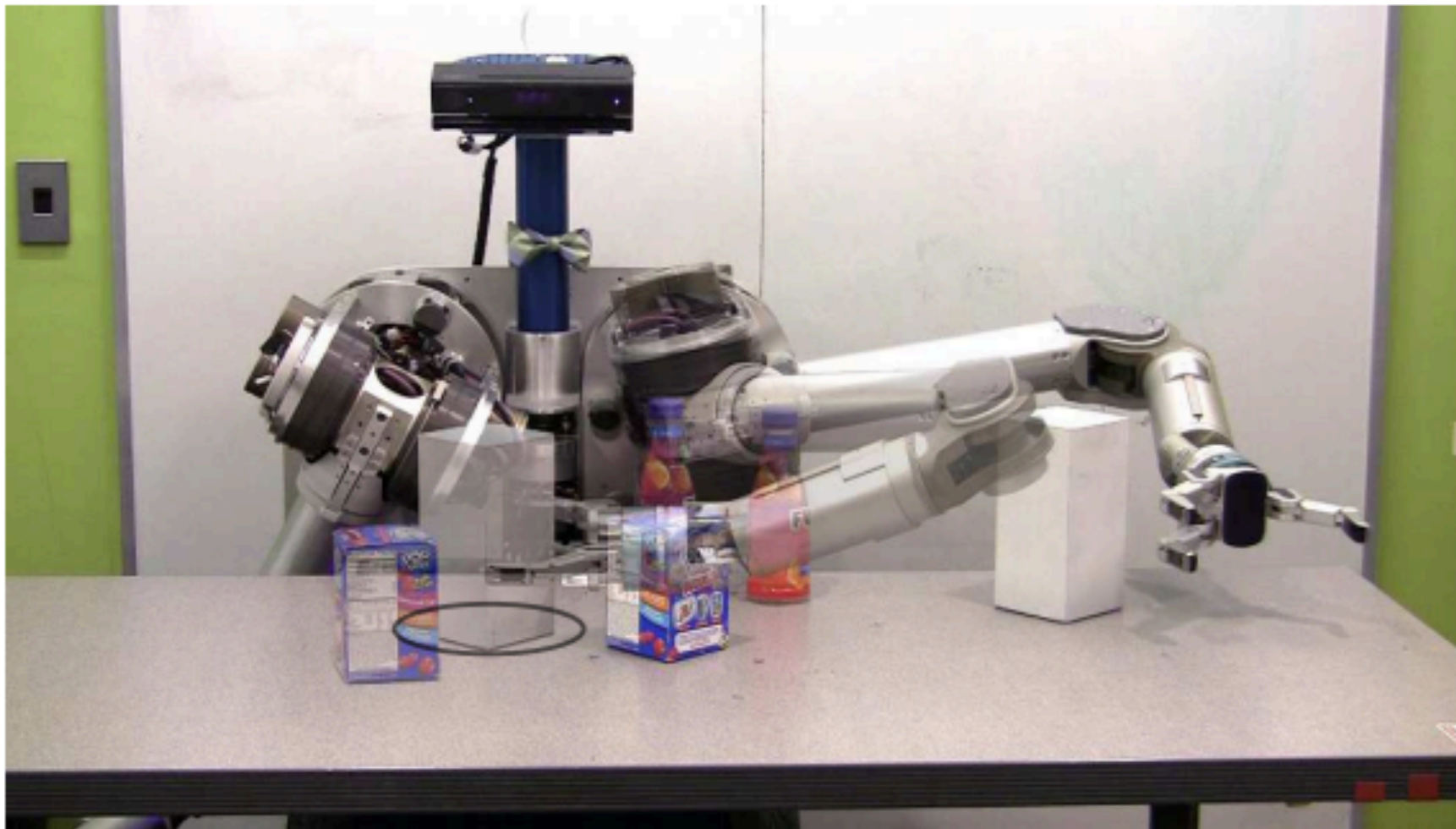
joint work with

Siddhartha Srinivasa
Aaron Johnson
Shushman Choudhury
Michael Koval
Matthew Harding

Jennifer King
Pras Velagapudi
Christopher Dellin
JS Lee
...



Task: Push the box to the middle of the table.



Challenge 1

Can we incorporate uncertainty in simulation?

- Deterministic dynamics with state and control noise

$$\begin{aligned}x_0 &\sim \mathcal{N}(\mu_0, \Sigma_0) \\x_{t+1} &= f(x_t, u_t) \\u_t &= \pi(x_t) + \epsilon, \quad \epsilon \sim \mathcal{N}(\mathbf{0}, \Sigma_\epsilon)\end{aligned}$$

- Stochastic dynamics

$$x_{t+1} = f(x_t, u_t) + g(x_t, u_t)dw$$

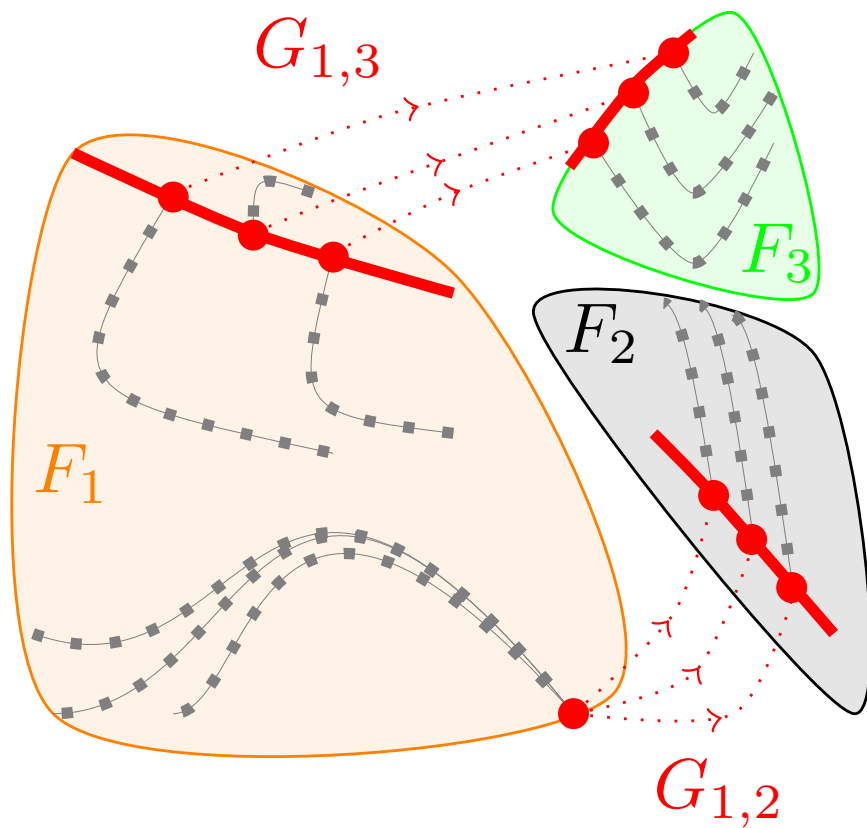
- Can we get the distribution of trajectories without performing rollouts?

Challenge 1

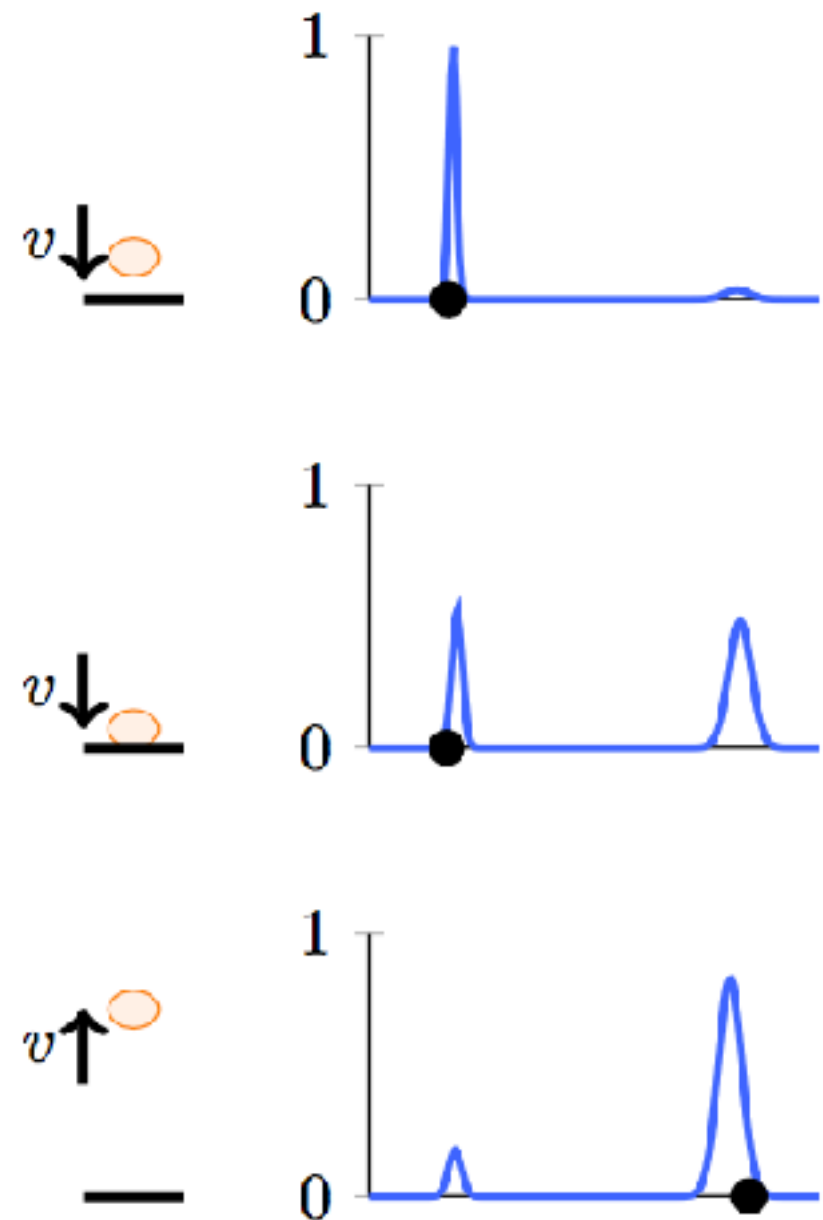
Can we incorporate uncertainty in simulation?

- Representing the trajectory distribution
 - Gaussian approximation μ_t, Σ_t
 - Approximation of full distribution
- Can we do more efficient rollouts?
 - Parallelization, sharing bodies across rollouts
 - Single rollout in collision-free segment, multiple rollouts around collision

Predicting multi-modal state distribution near collision



Stochastic Hybrid System



Pre-collision Post-collision

Challenge 2

Can simulator reconstruct real-world trajectories?

- Given a set of real-world control inputs and resulting trajectories, can we optimize a simulator to produce same input-outputs?
- Key step necessary to use simulated result in real world
- Less importance on getting the parameters right, more importance on matching the input-output
- How much confidence does the optimized simulator guarantee?
- To what extent can we use the optimized simulator?

Challenge 2

Can simulator reconstruct real-world trajectories?

1. Deterministic dynamics, noisy initial state distribution

- System Identification
- Choice of which parameters to tune
- Choosing the error metric

2. Noisy control input or stochastic dynamics

- Tune the noise covariance
- Can multiple rollouts result in the same trajectory distribution?

Reducing the Reality Gap

- Simulating uncertainty
- Reconstructing real-world trajectories
- How do we measure the Reality Gap?