

Guided Learning of Control Graphs for Physics-Based Characters

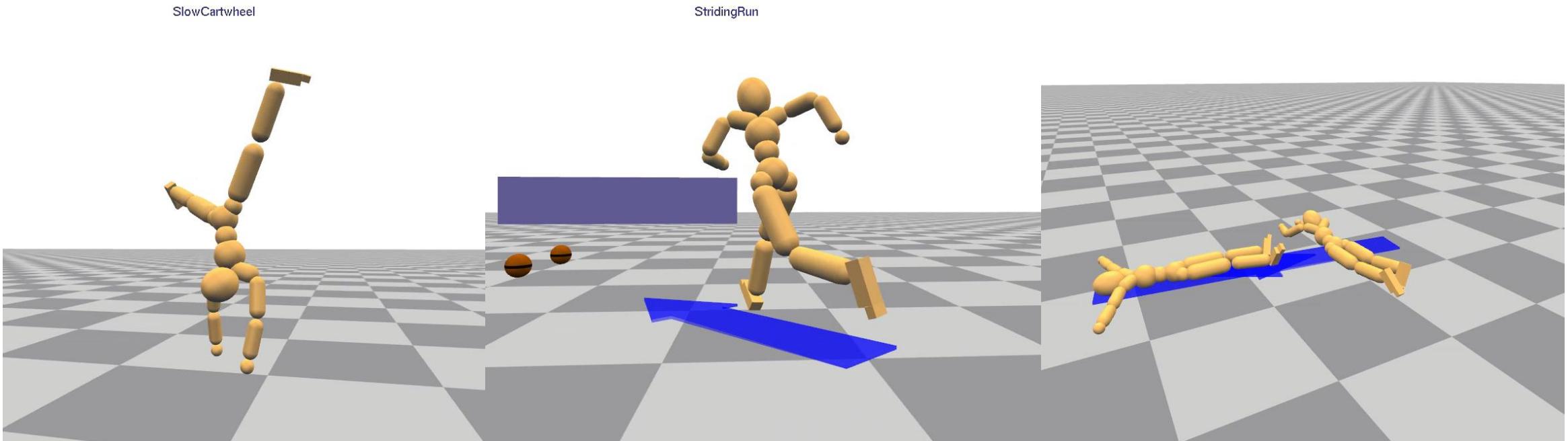
Libin Liu¹ Michiel van de Panne¹ KangKang Yin²

¹The University of British Columbia

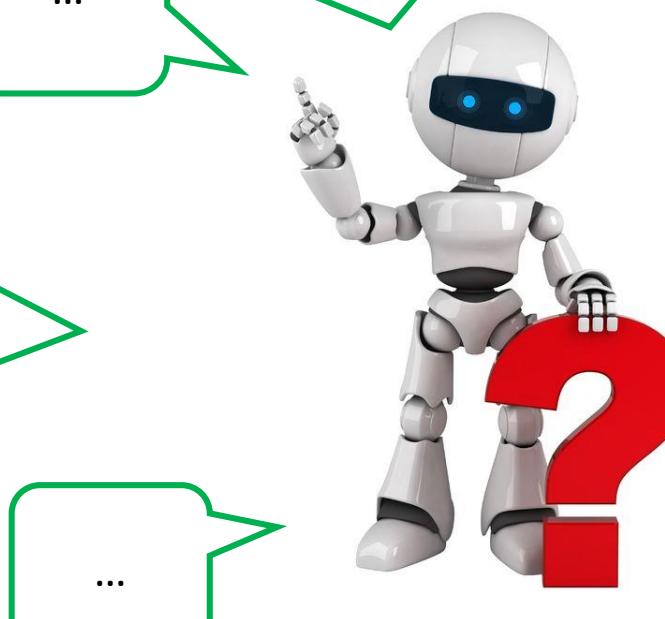
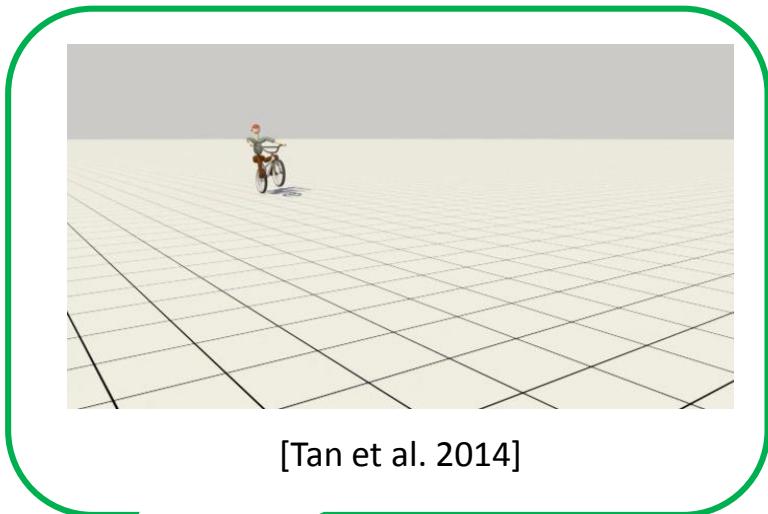
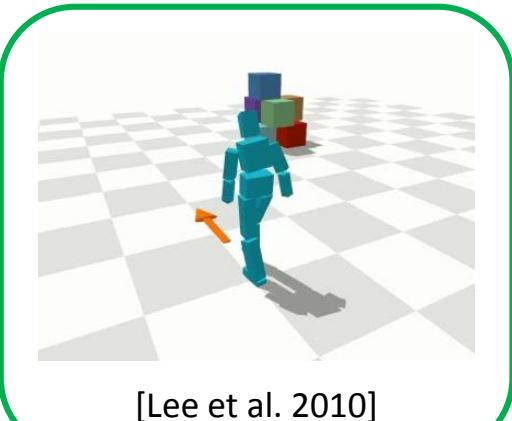
²National University of Singapore



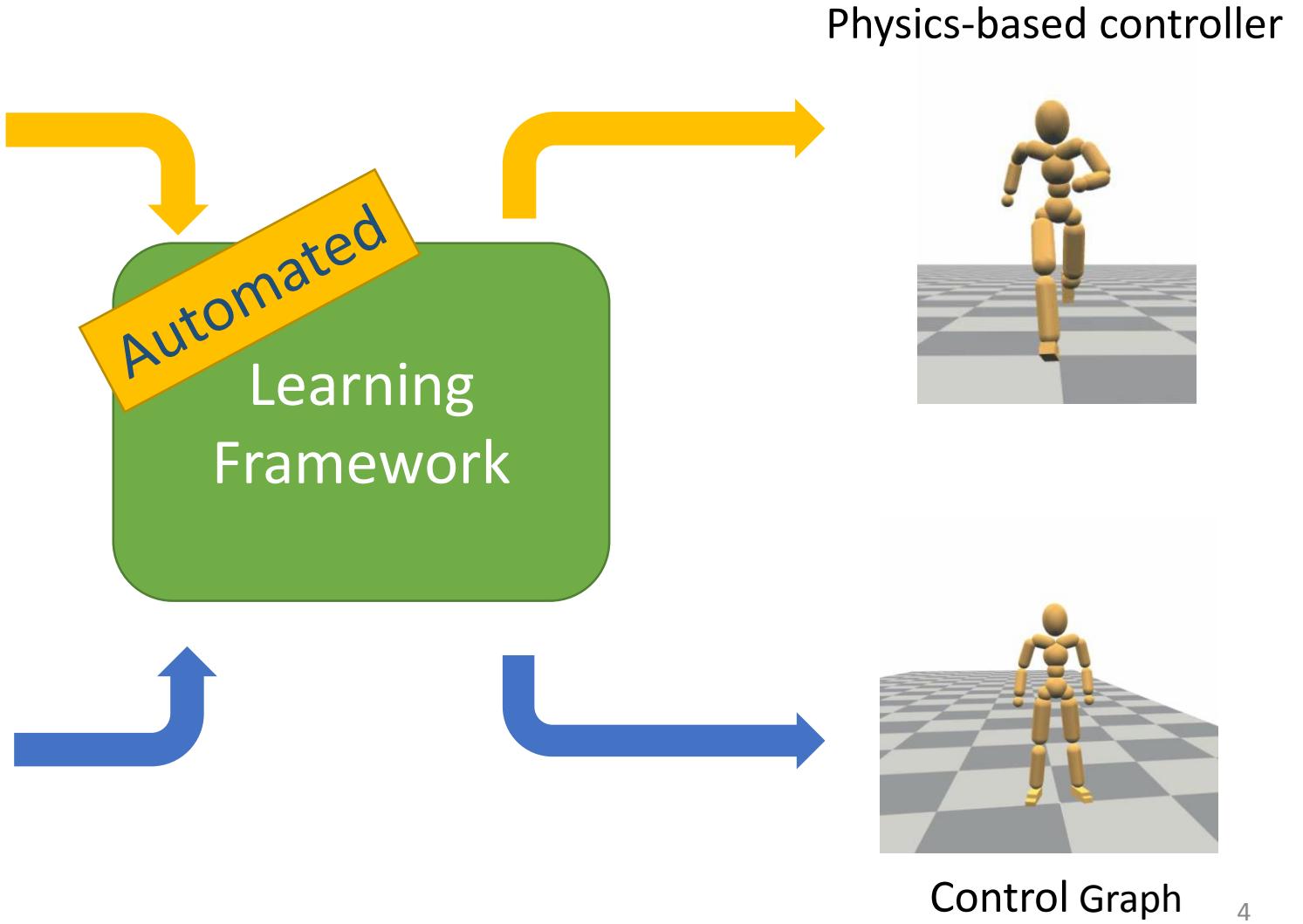
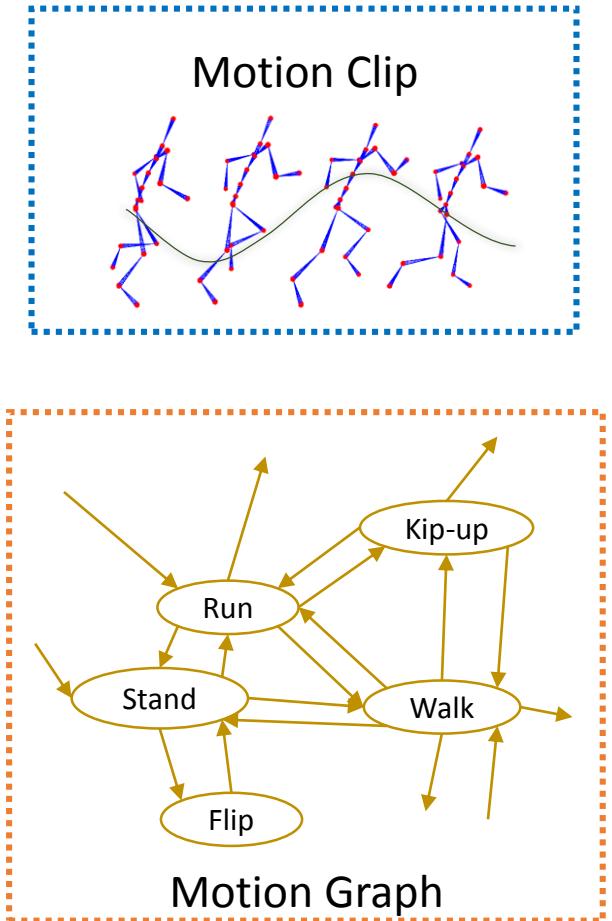
Why Physics-based Characters?



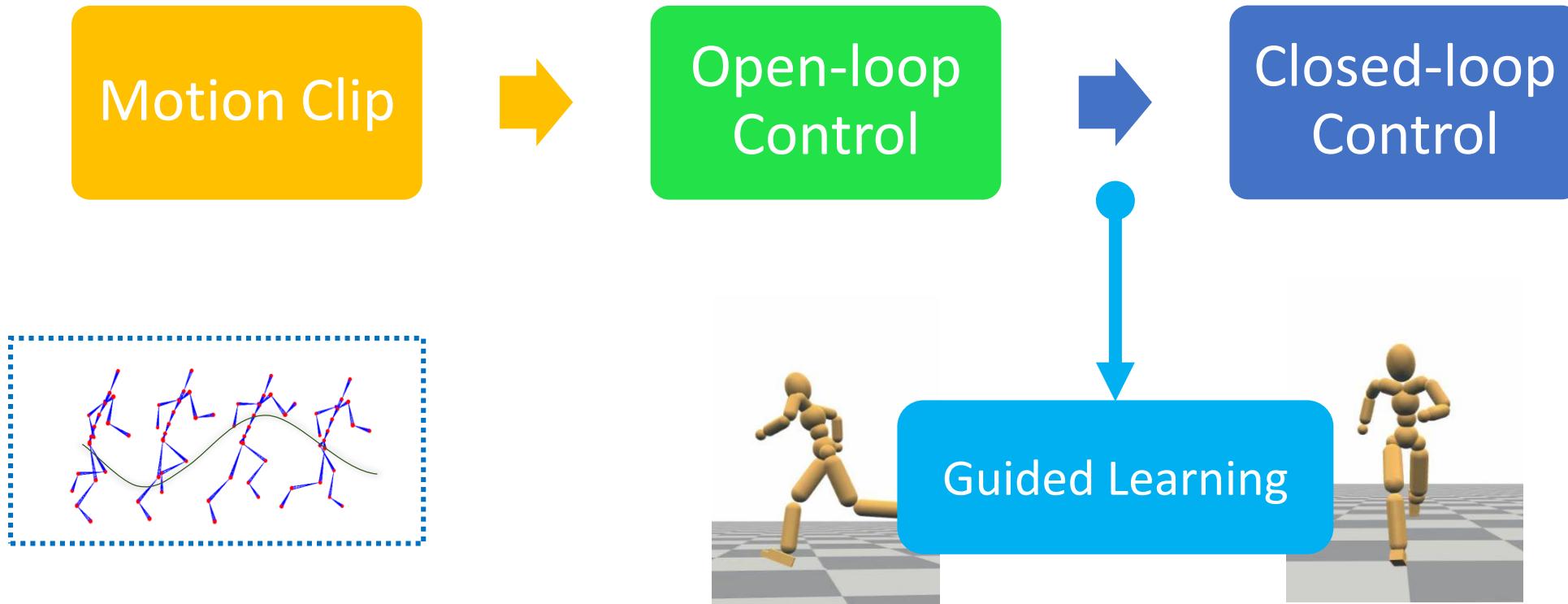
Existing Solutions



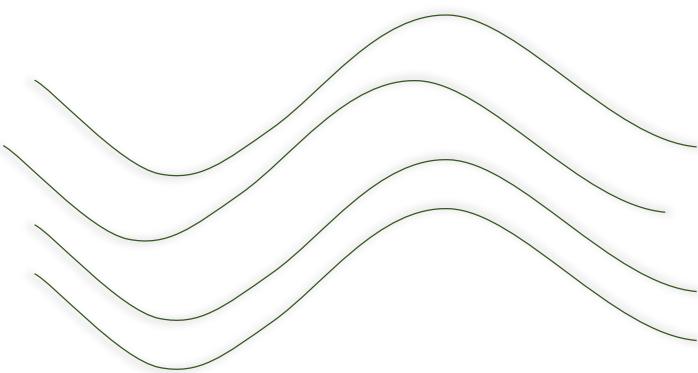
Our Goal



Pipeline



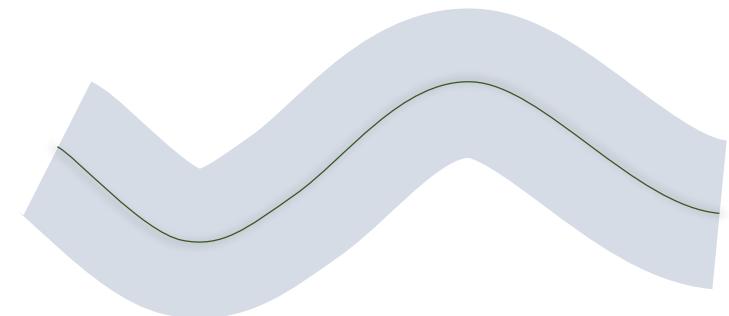
Key Intuition



Multiple Open-loop Solutions

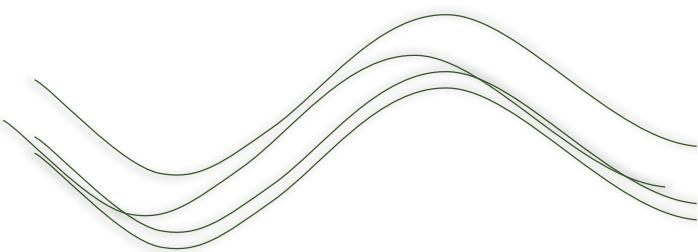


Regression

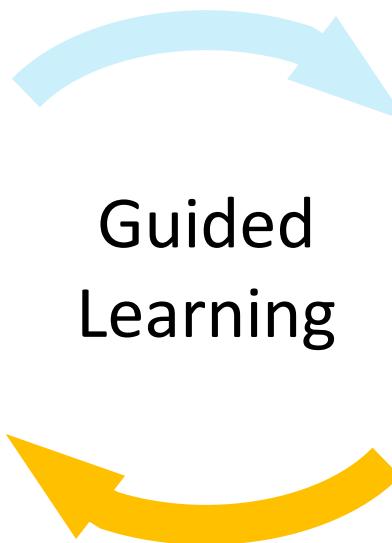


Feedback Policy

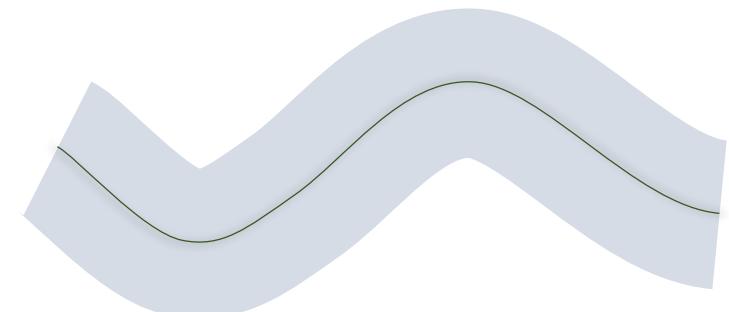
Key Intuition



Multiple Open-loop Solutions

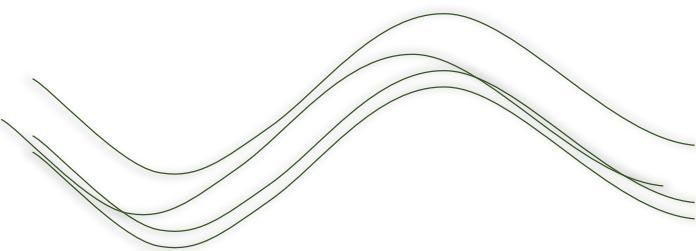


Guided
Learning



Feedback Policy

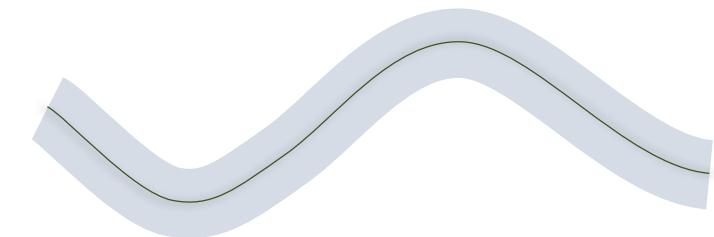
Key Intuition



Multiple Open-loop Solutions

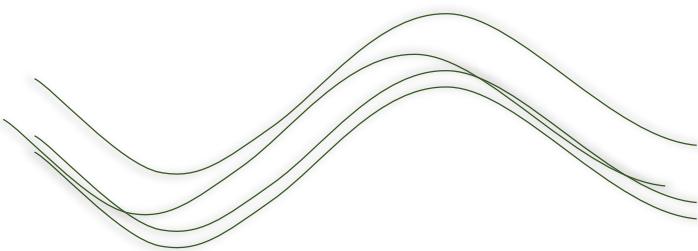


Guided
Learning



Feedback Policy

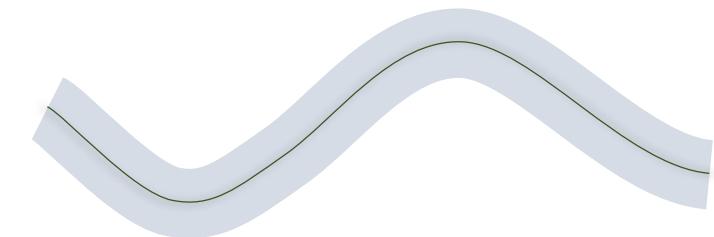
Key Intuition



Multiple Open-loop Solutions



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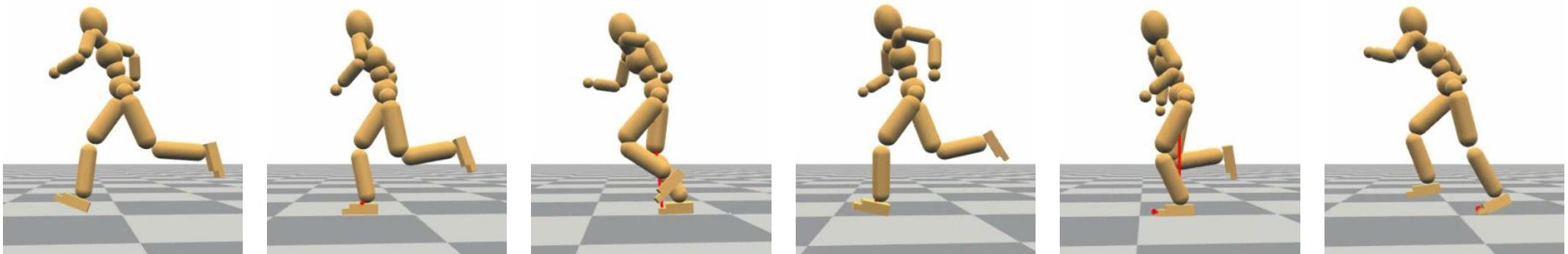
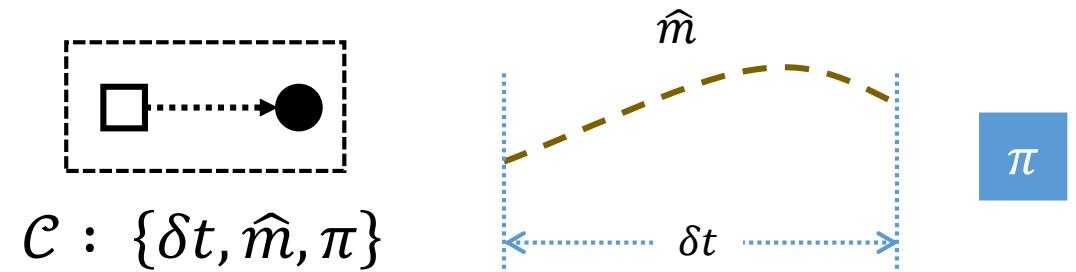


Feedback Policy

Control Fragment

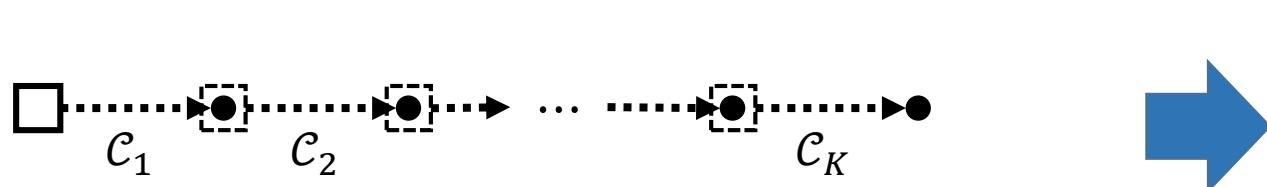
A short control unit:

- $\delta t \approx 0.1$ seconds long
- Open-loop control segment \hat{m}
- Linear Feedback policy π

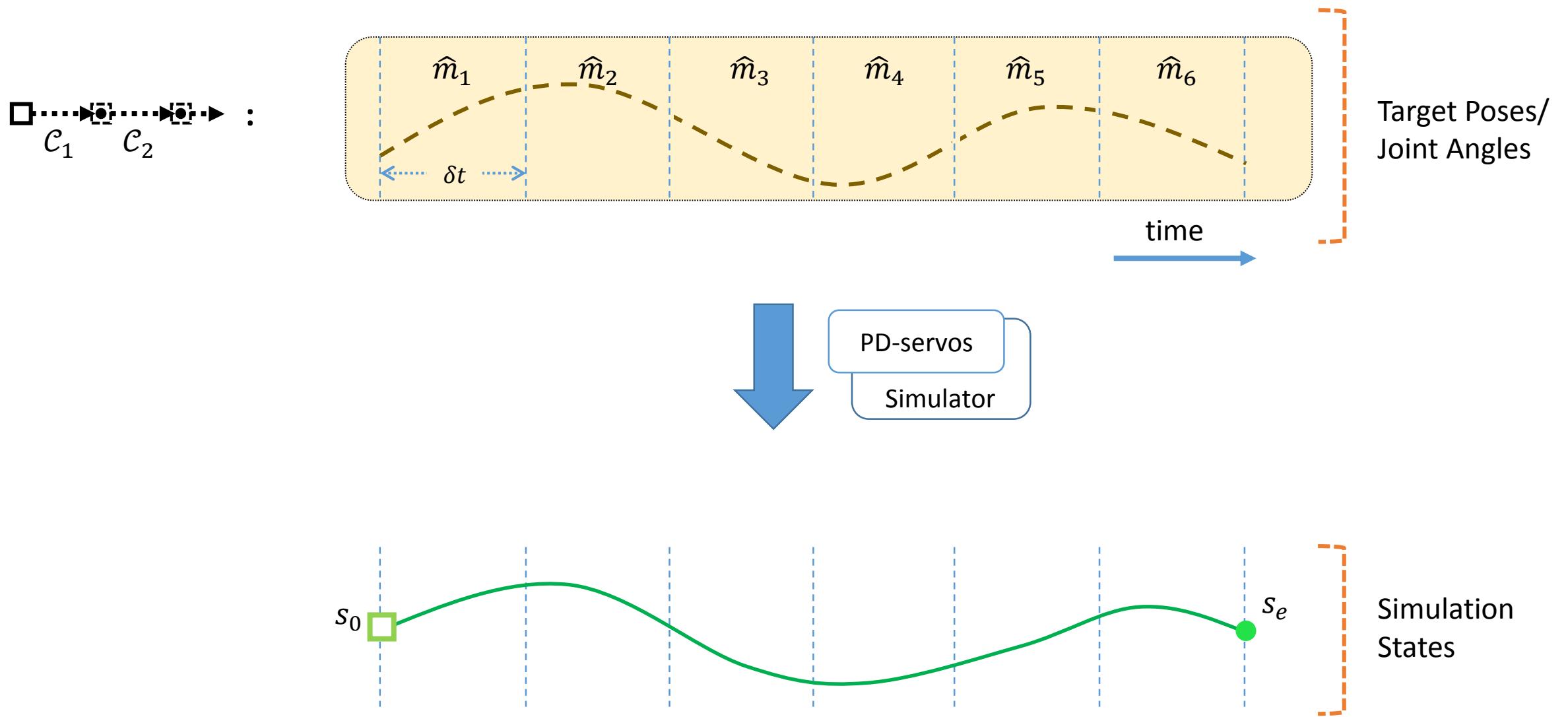


Controller

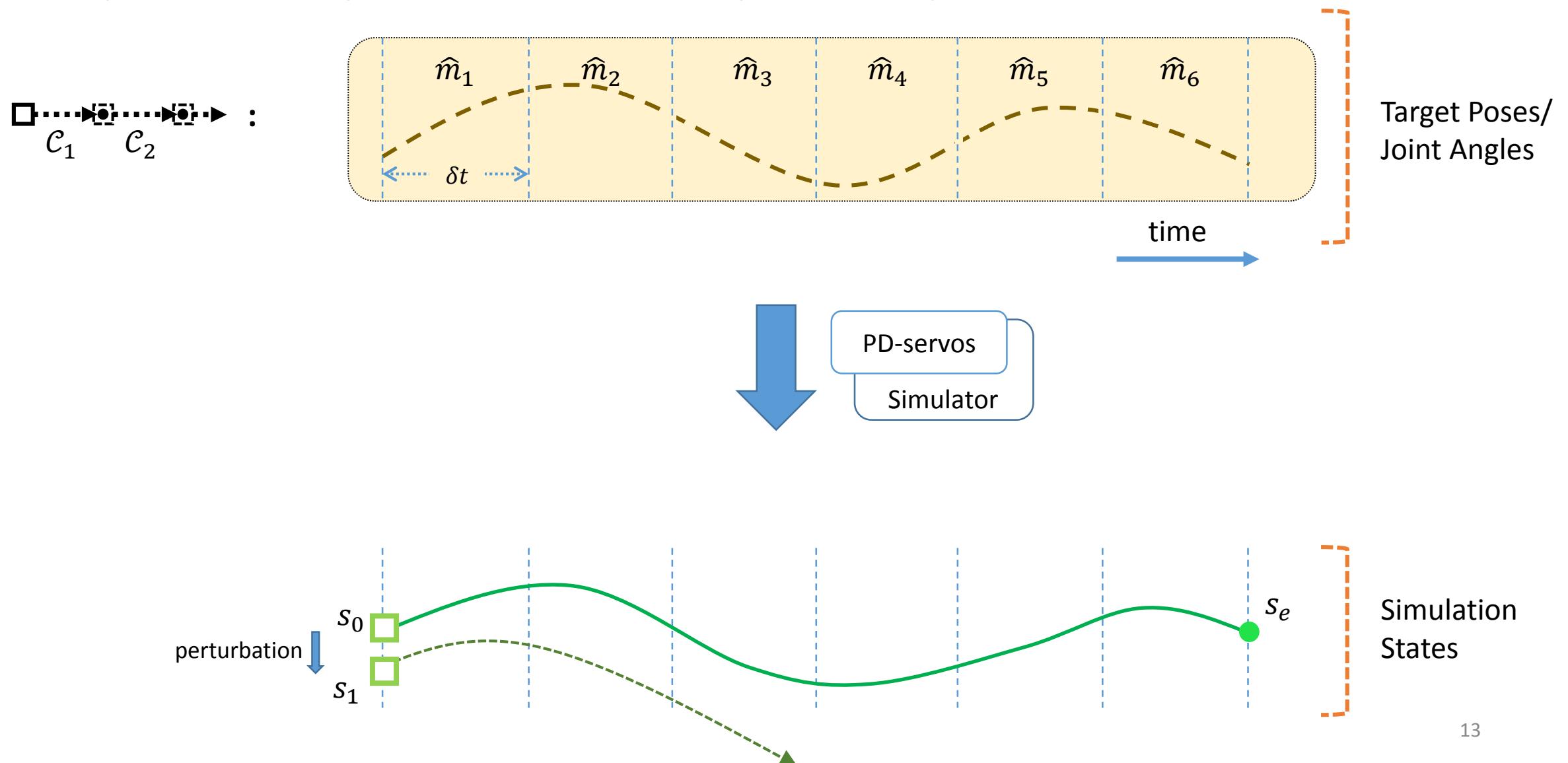
A chain of control fragments



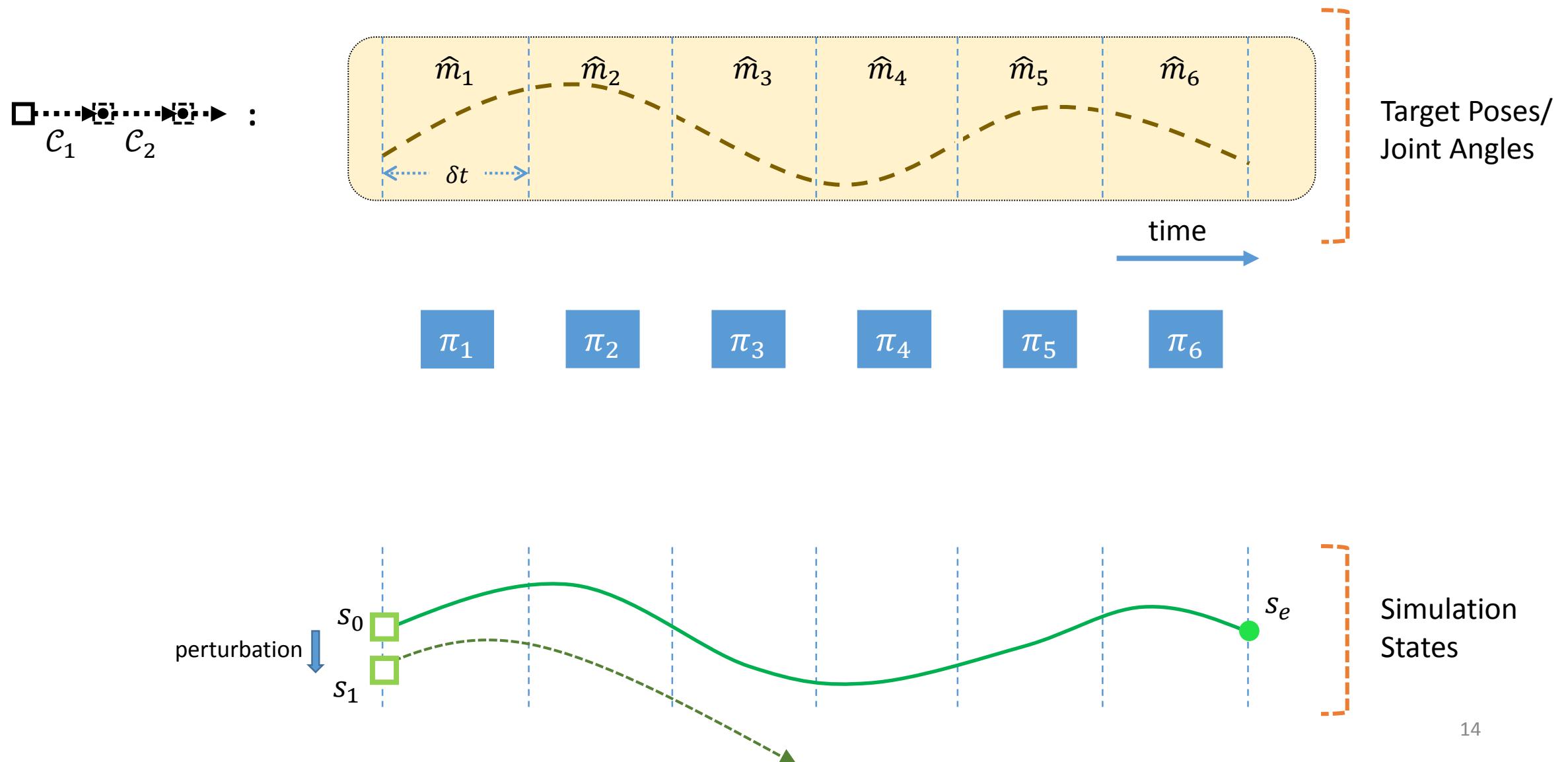
Open-loop Control Trajectory



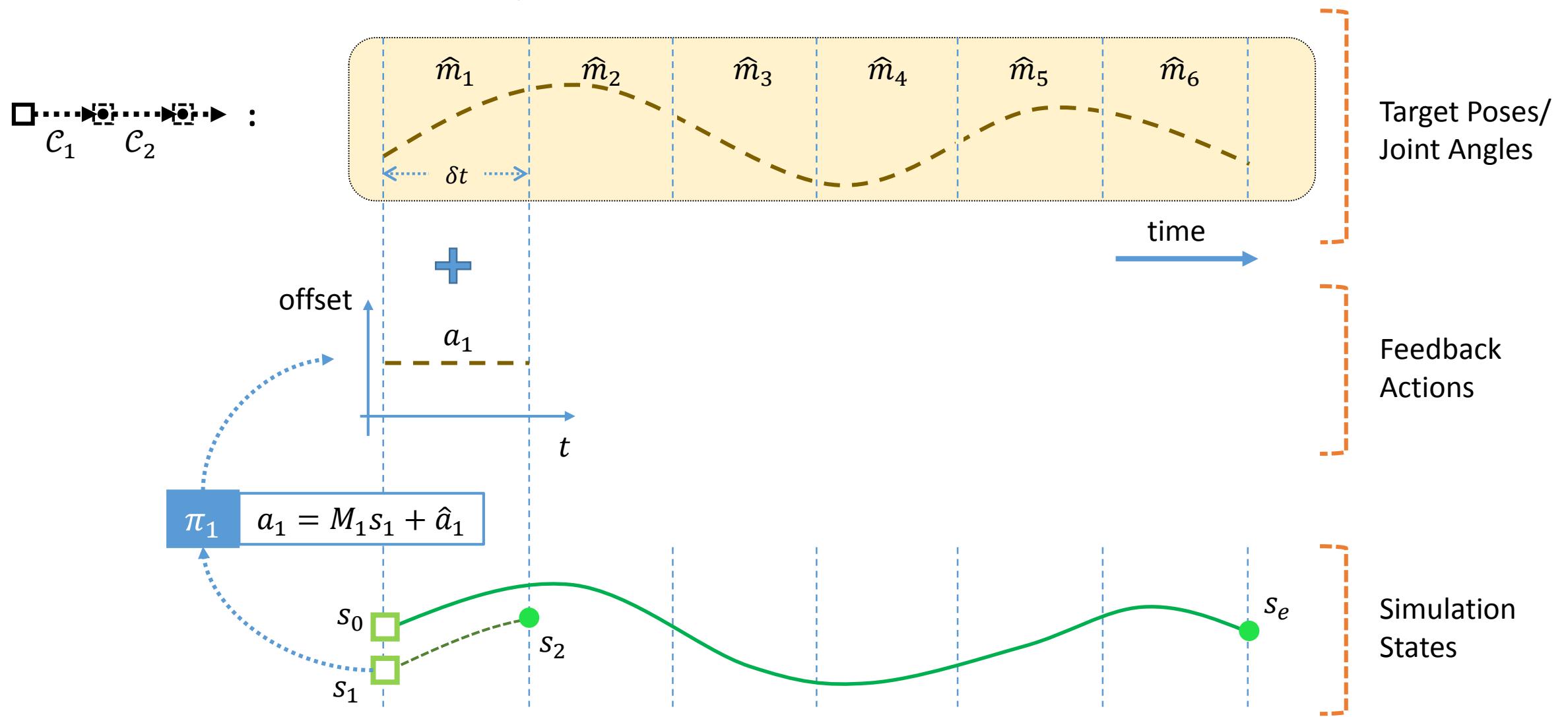
Open-loop Control Trajectory



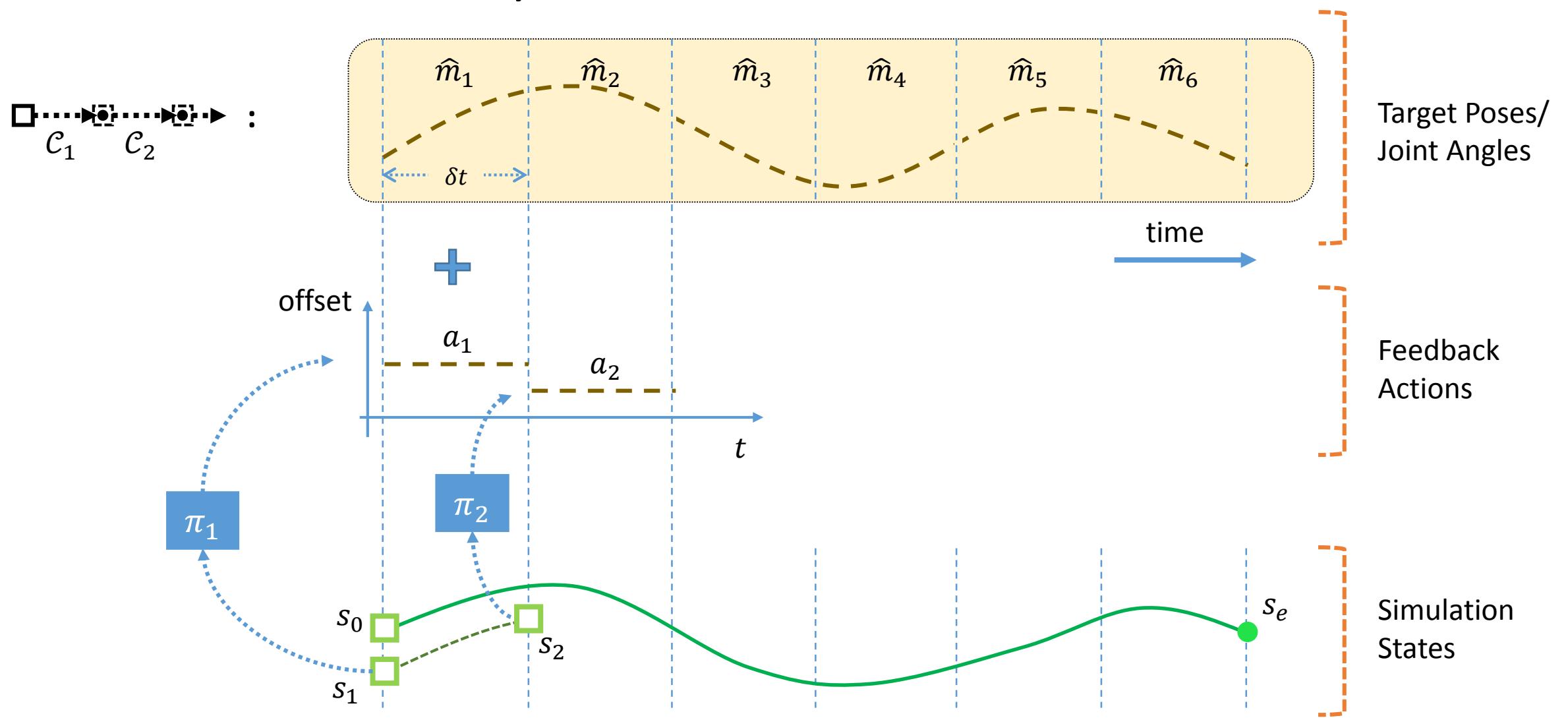
Open-loop Control Trajectory



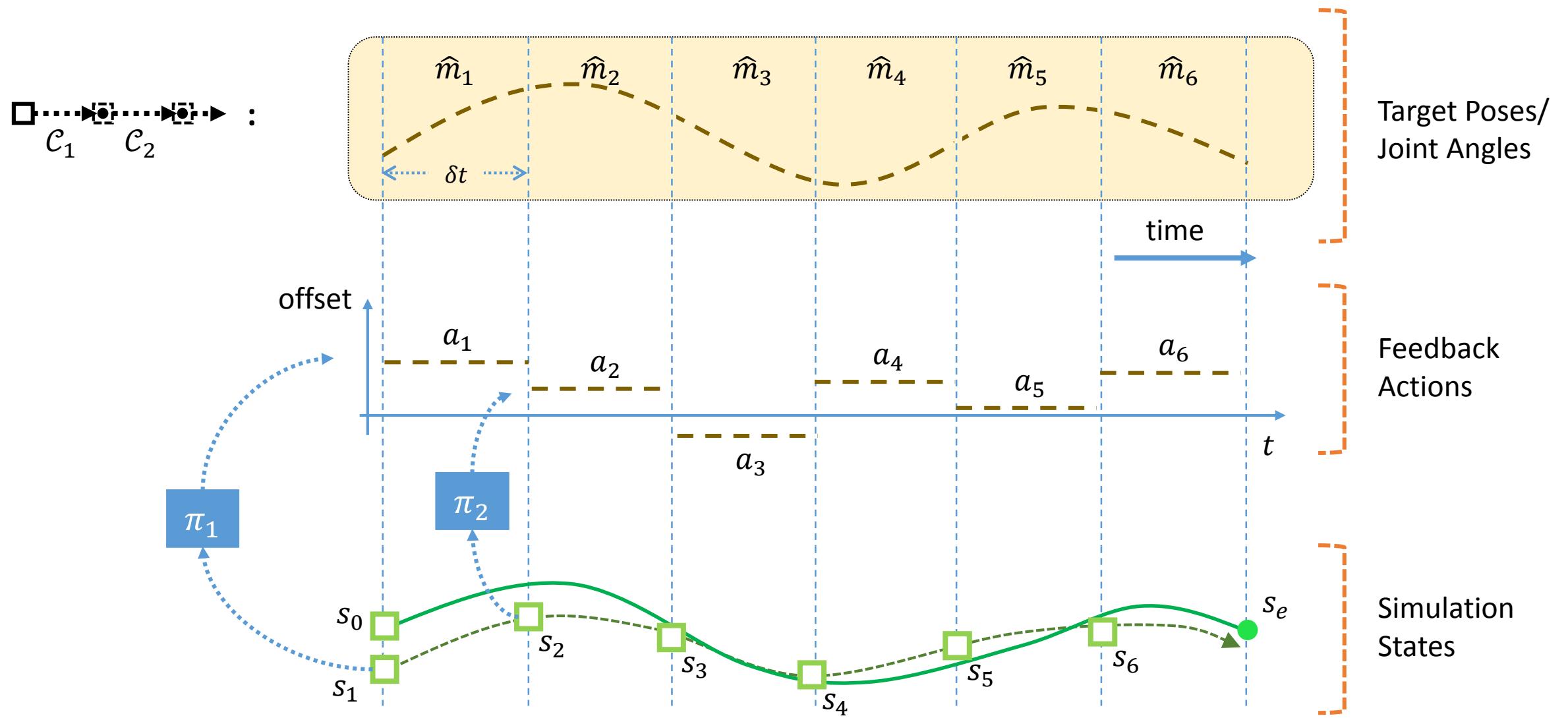
Feedback Policy



Feedback Policy



Feedback Policy

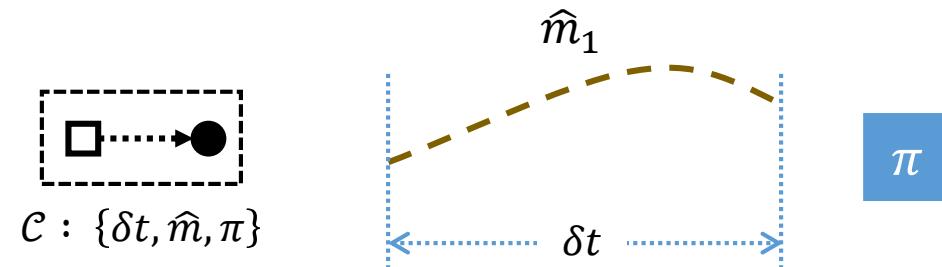


Learning of Control Fragments

What do we need to learn?

- Open-loop control trajectory \hat{m}
↑ SAMCON [Liu et al. 2010, 2015]

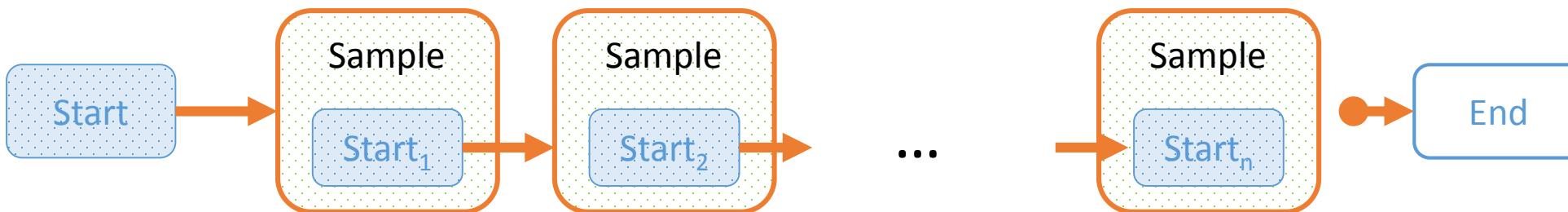
- Feedback policy π
↑ Guided SAMCON



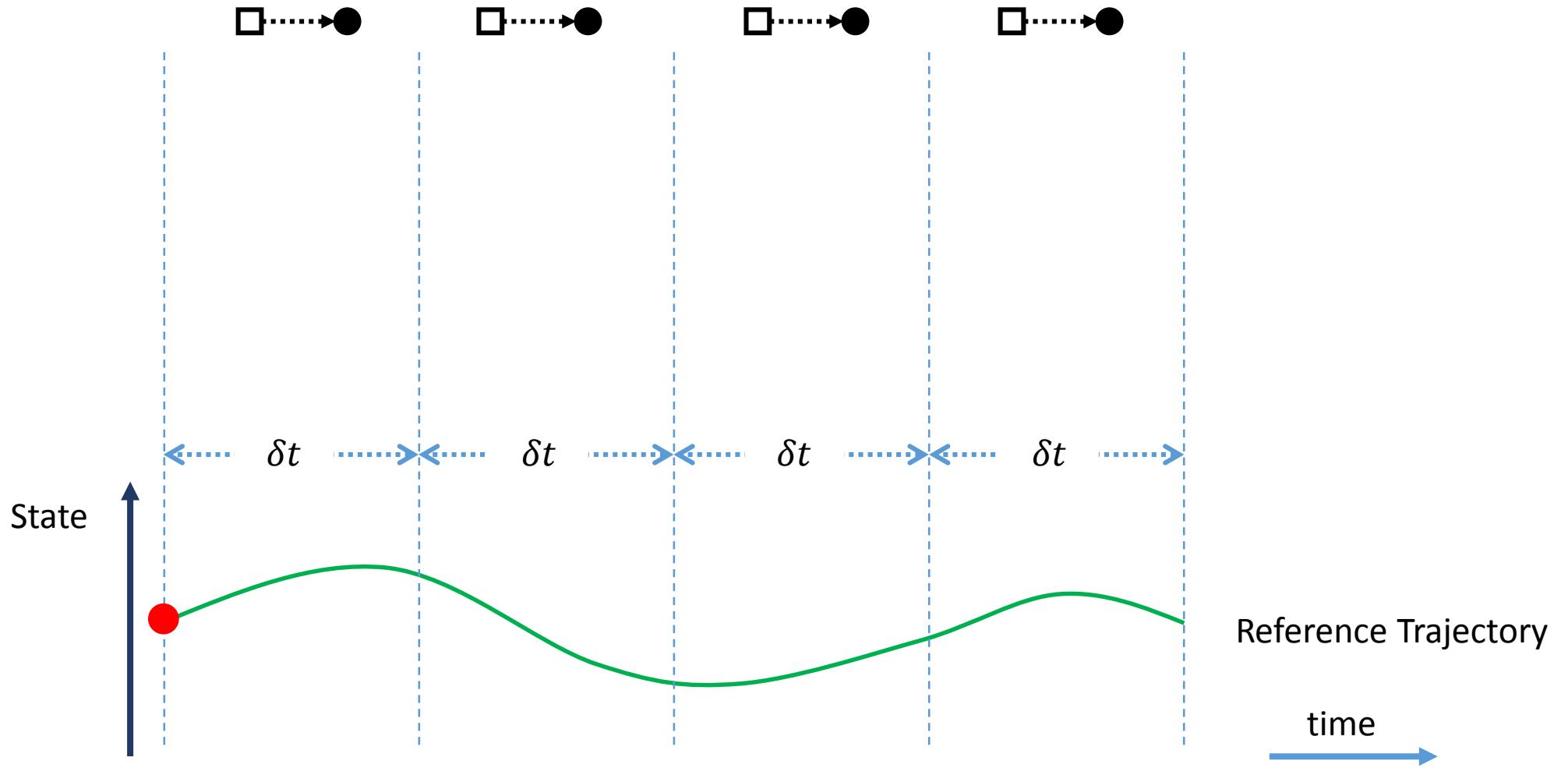
SAMCON

SAmpling-based Motion CONtrol [Liu et al. 2010, 2015]

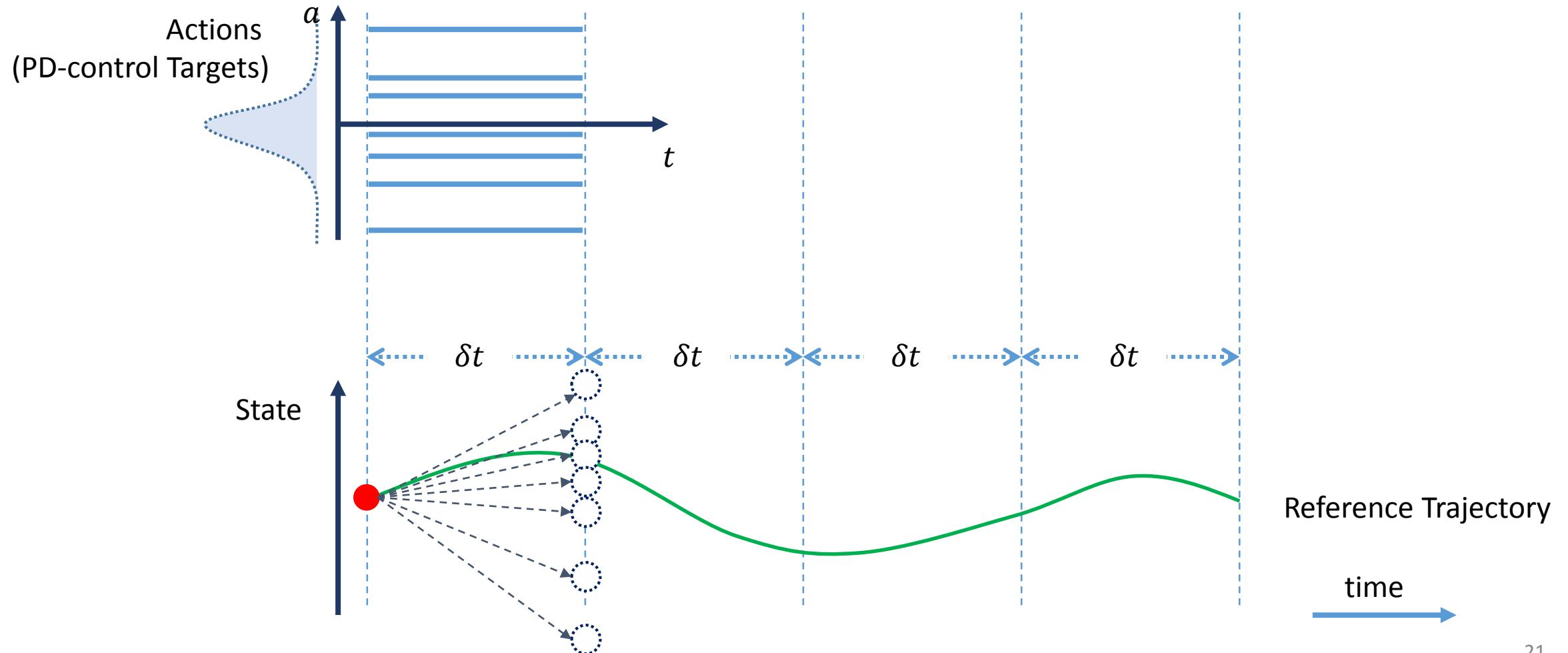
- Motion Clip → Open-loop control trajectory



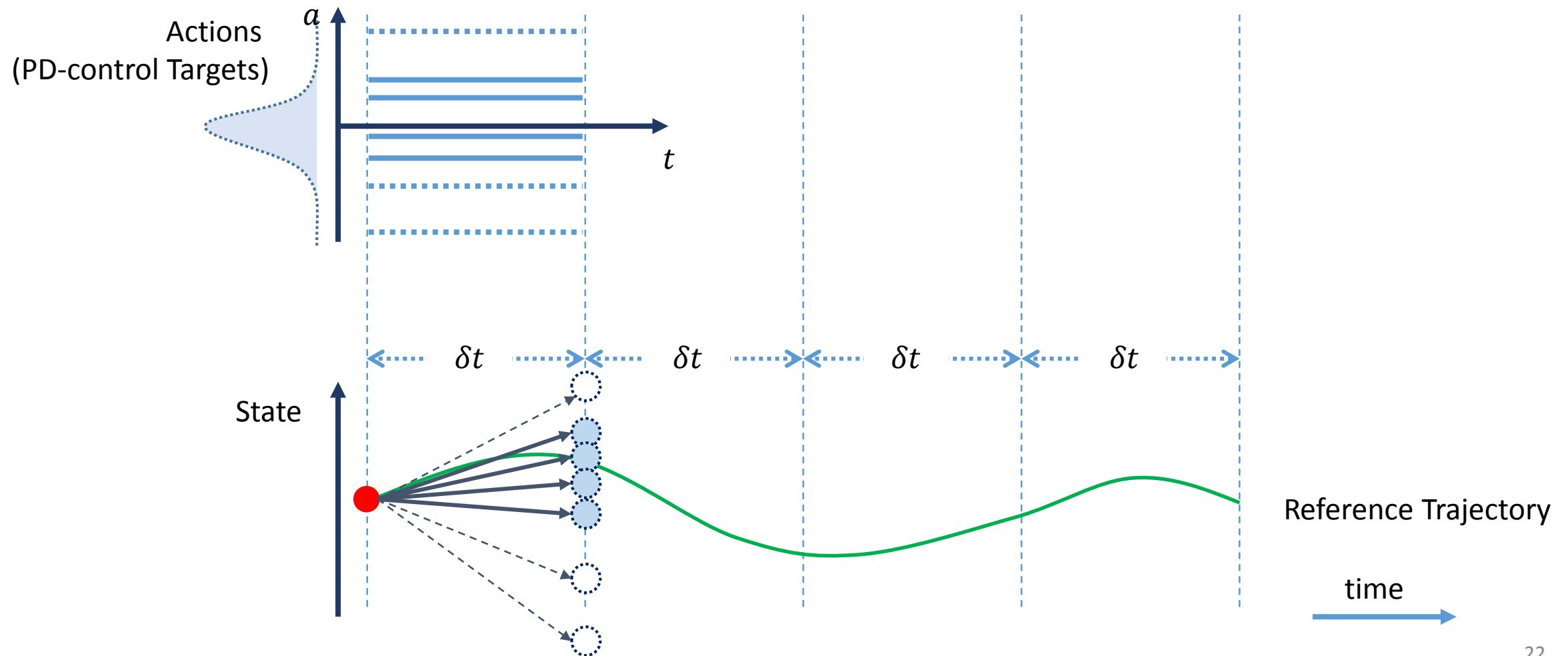
SAMCON



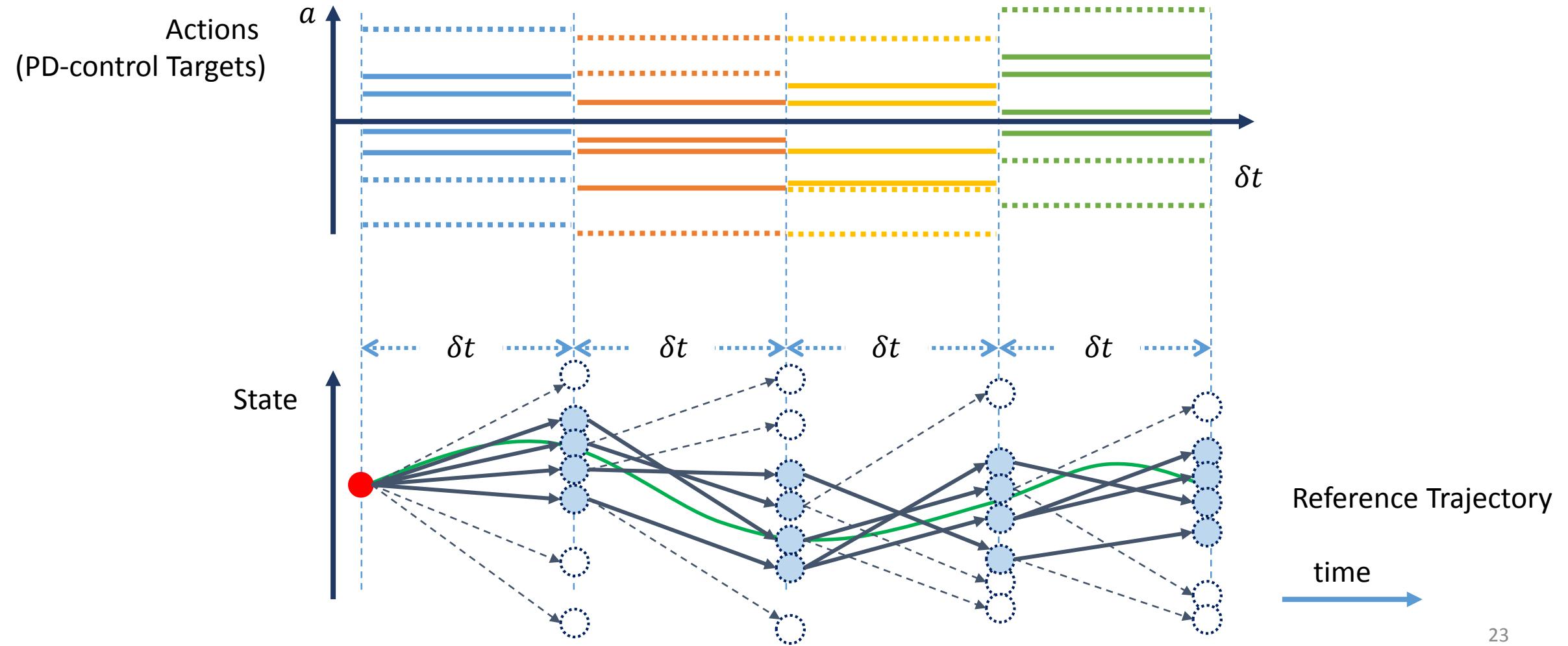
Sampling & Simulation



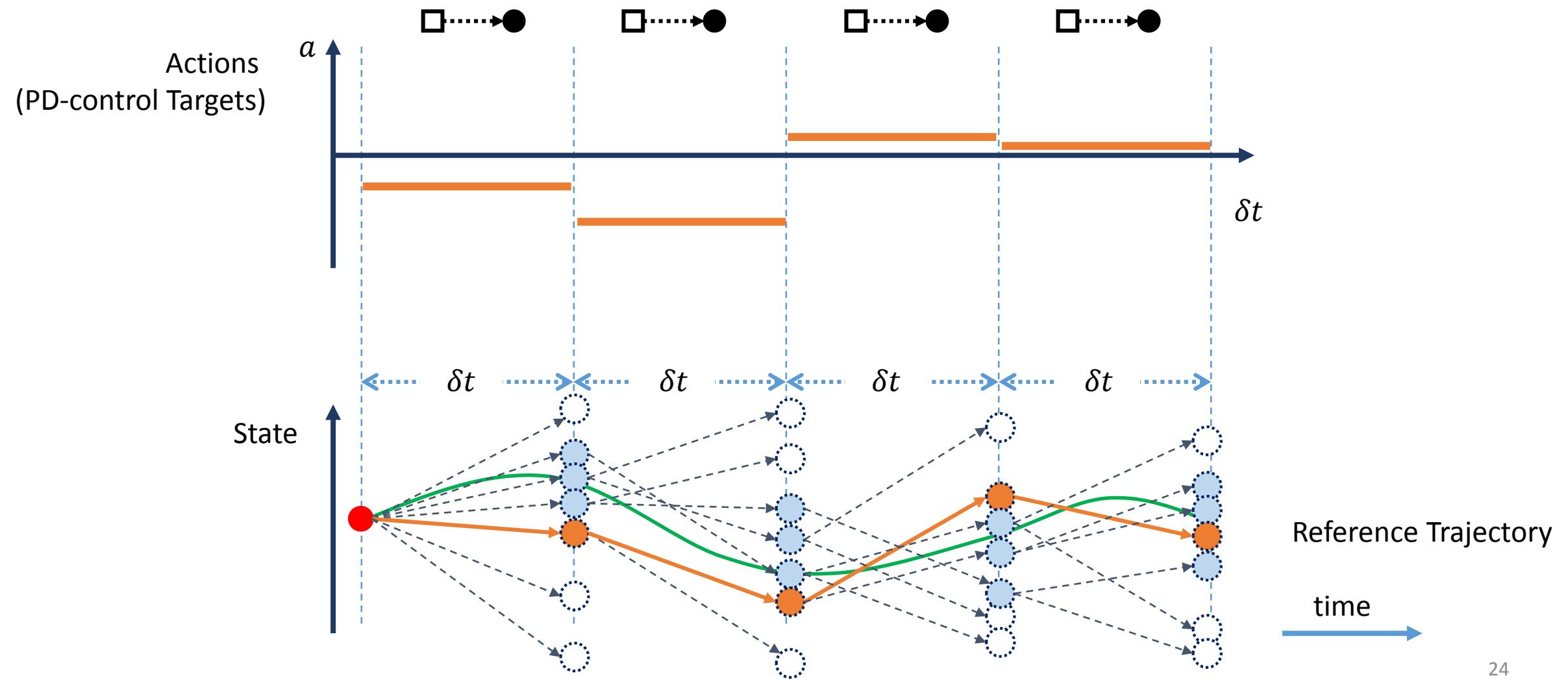
Sample Selection



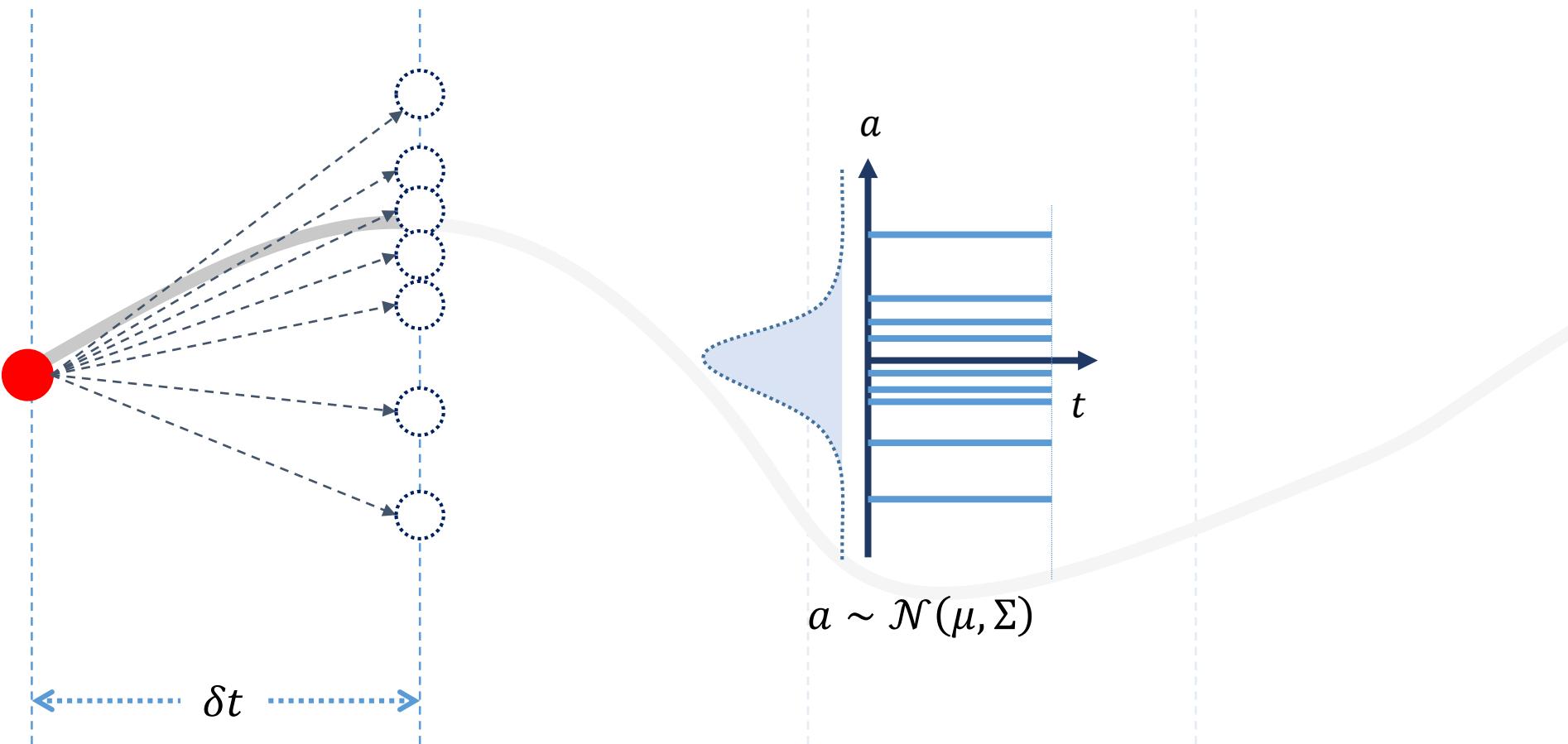
SAMCON Iterations



Constructed Open-loop Control Trajectory

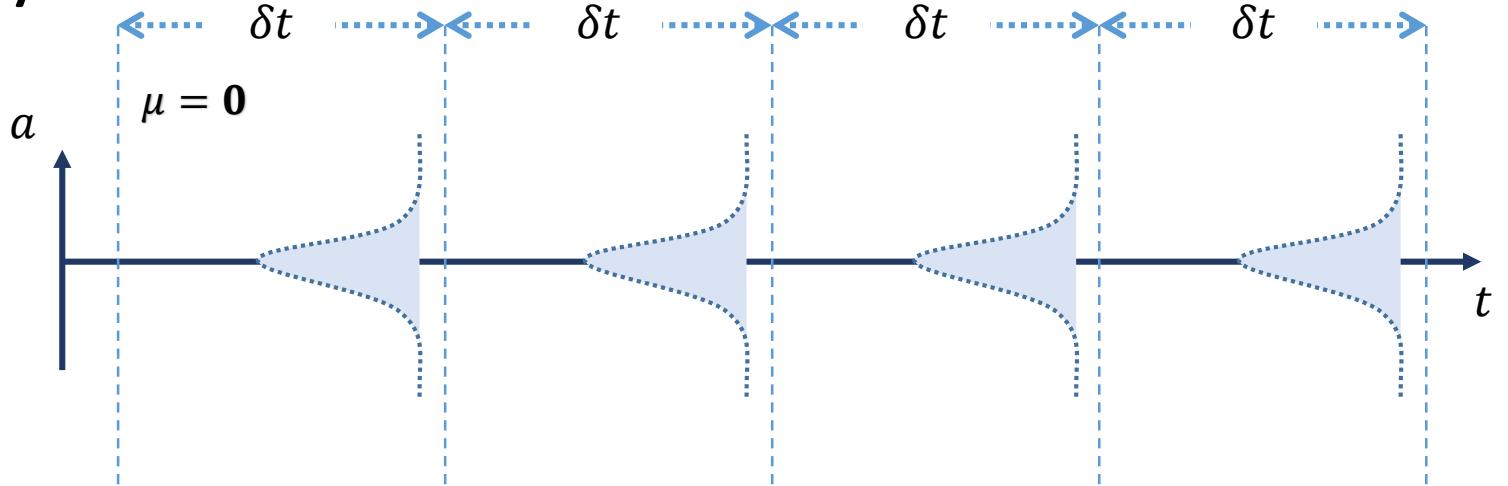


Sample Distribution



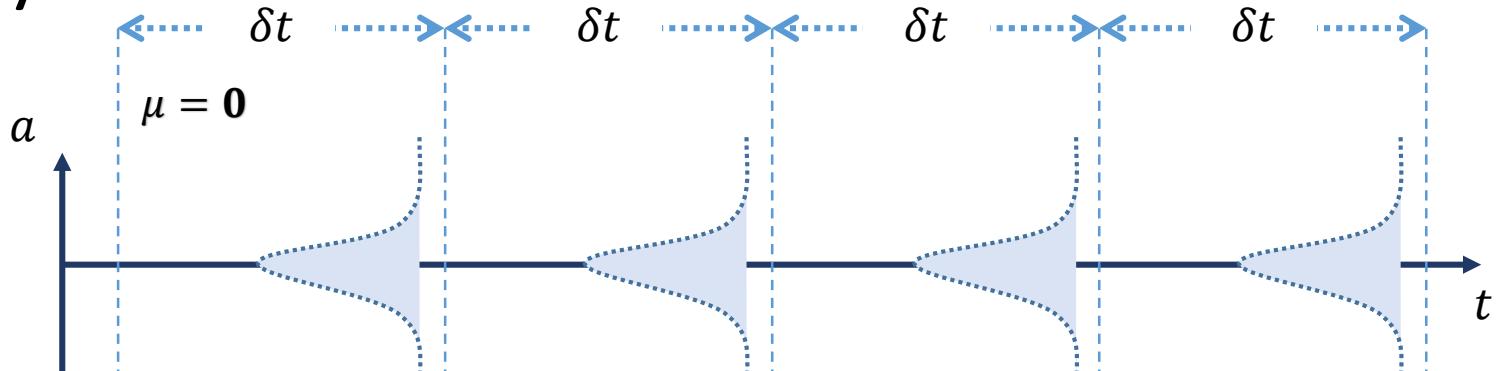
SAMCON Family

Original SAMCON
[Liu et al. 2010]

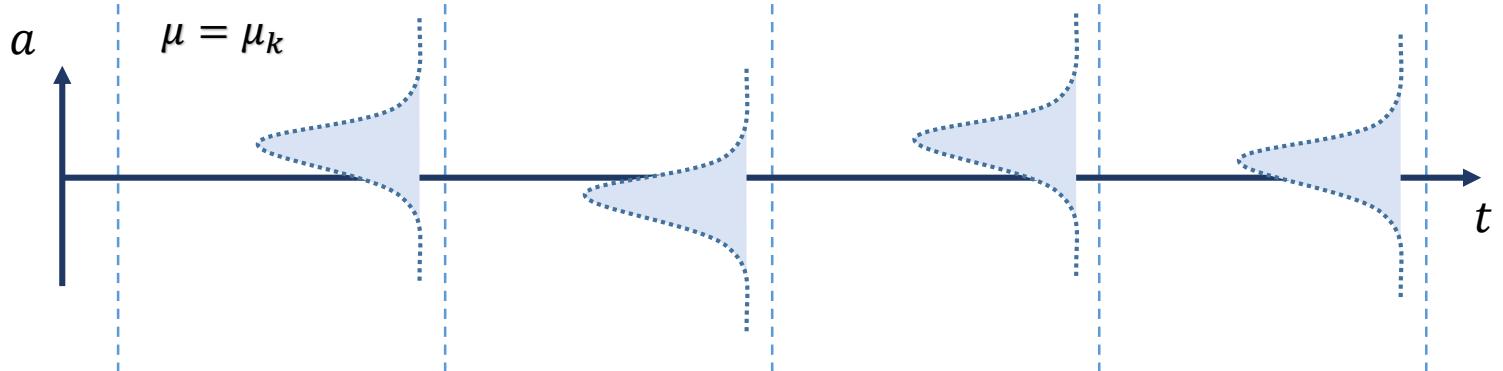


SAMCON Family

Original SAMCON
[Liu et al. 2010]

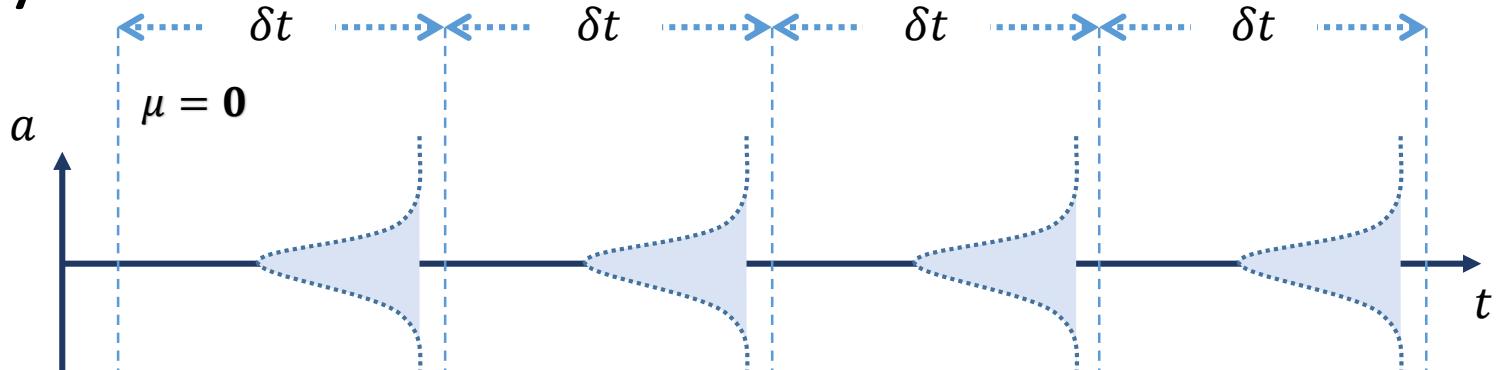


Improved SAMCON
[Liu et al. 2015]

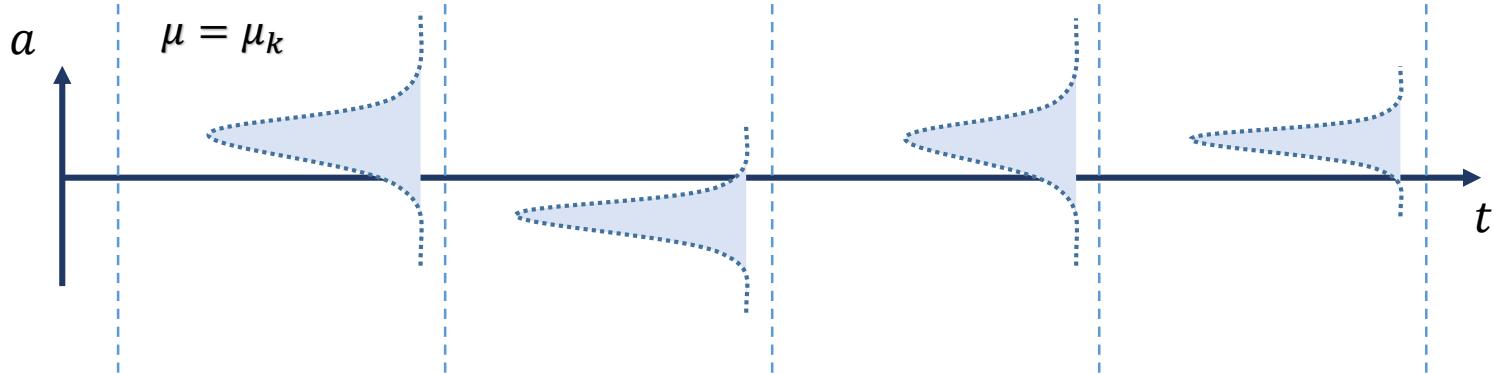


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[Liu et al. 2010]



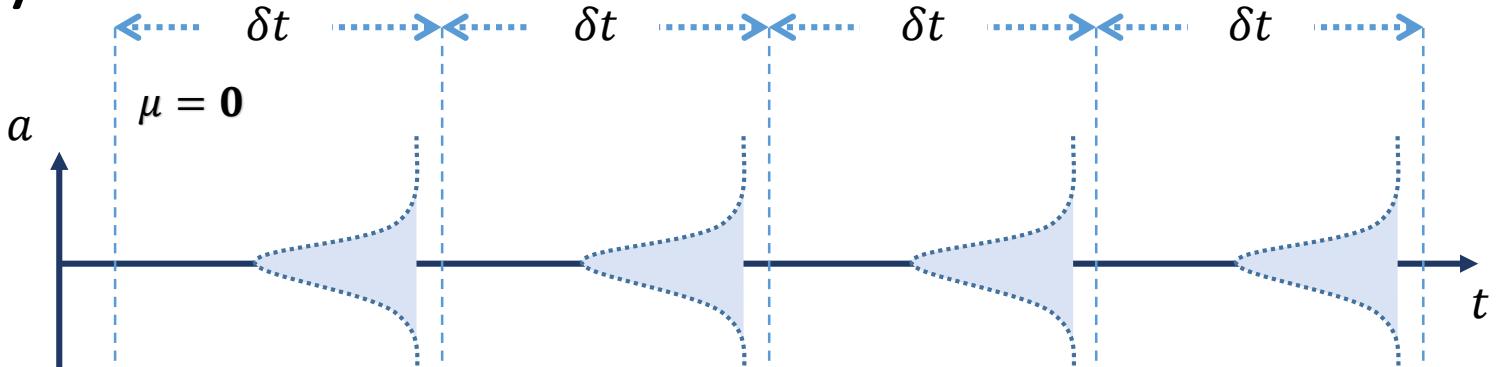
Improved SAMCON
[Liu et al. 2015]



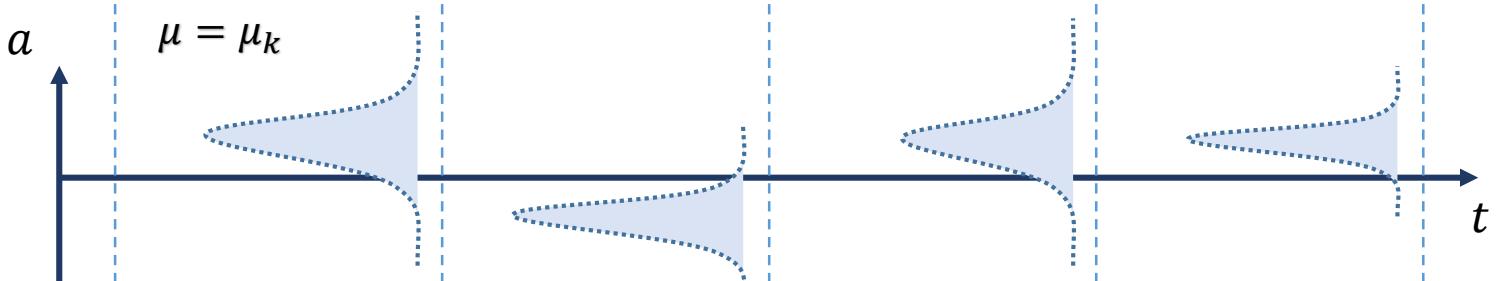
Guided SAMCON

SAMCON Family

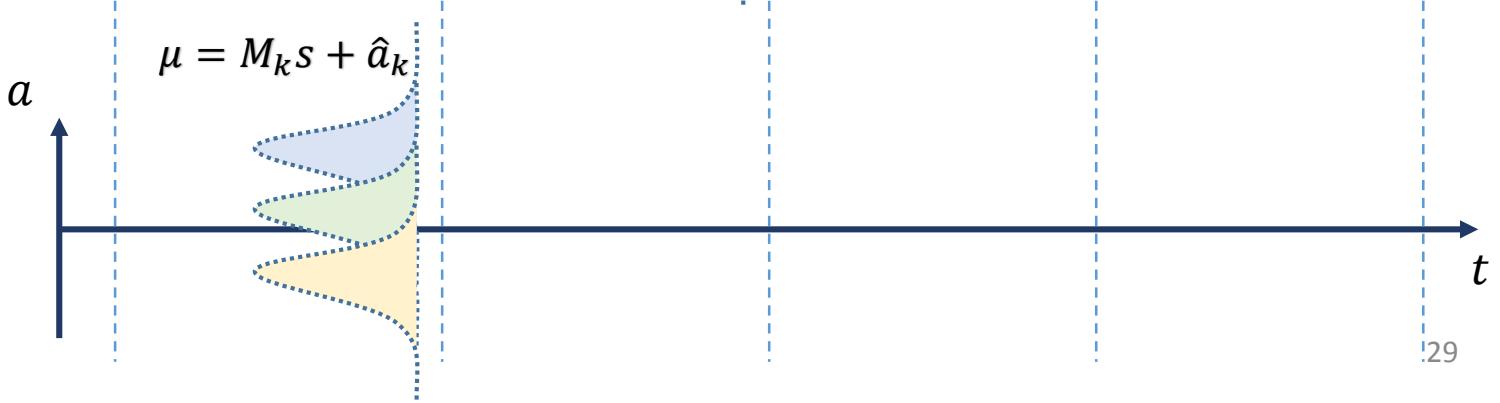
Original SAMCON
[Liu et al. 2010]



Improved SAMCON
[Liu et al. 2015]



Guided SAMCON

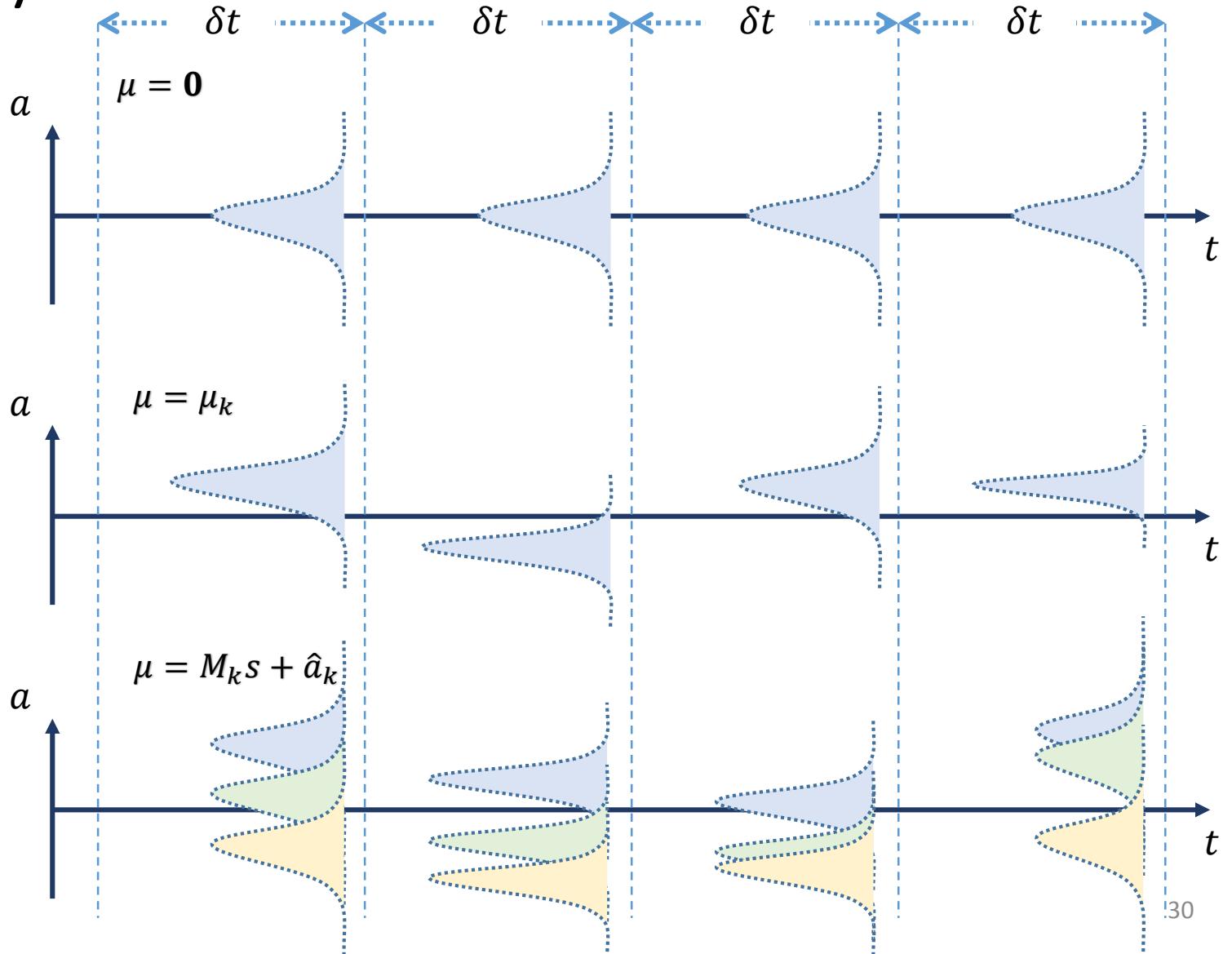


SAMCON Family

Original SAMCON
[Liu et al. 2010]

Improved SAMCON
[Liu et al. 2015]

Guided SAMCON



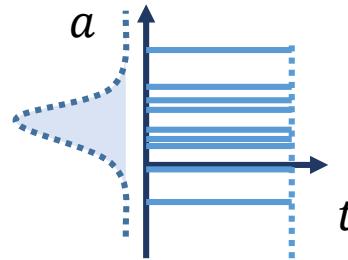
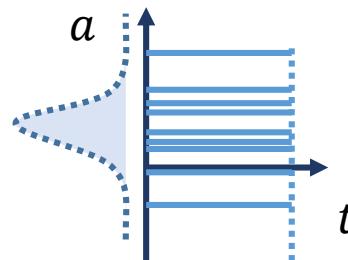
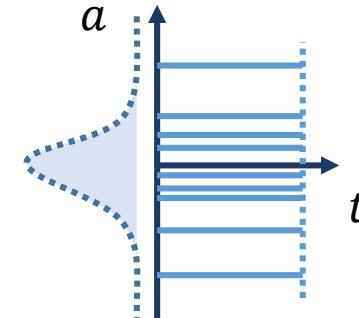
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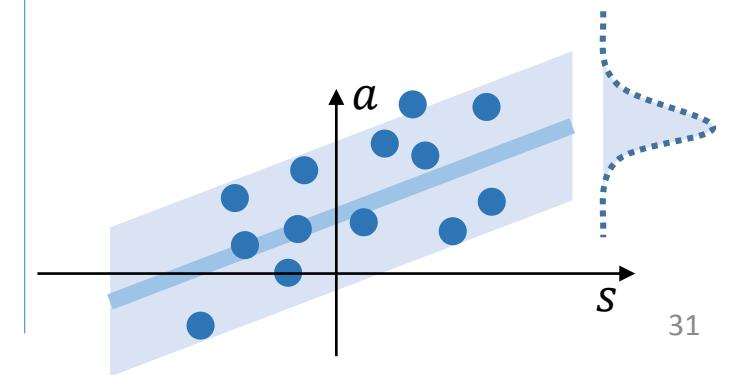
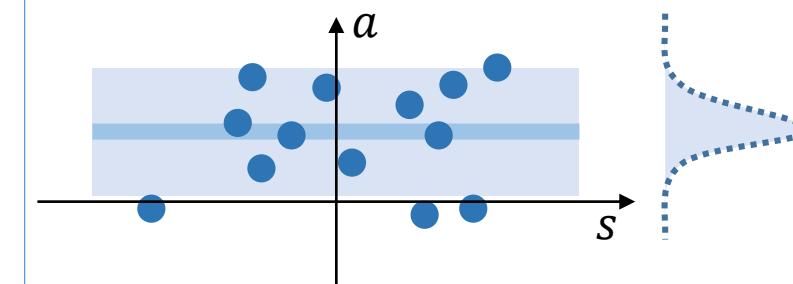
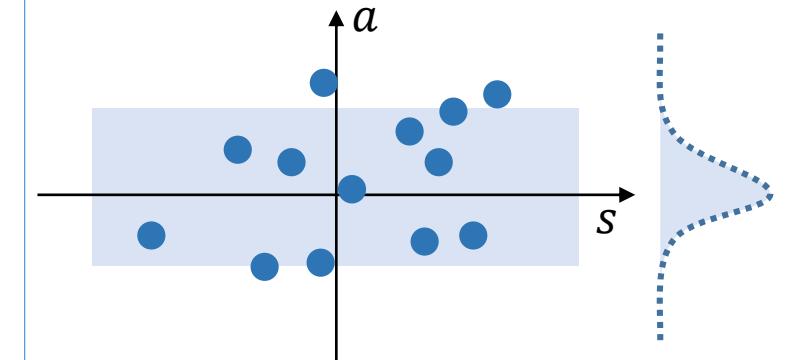
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Guided SAMCON

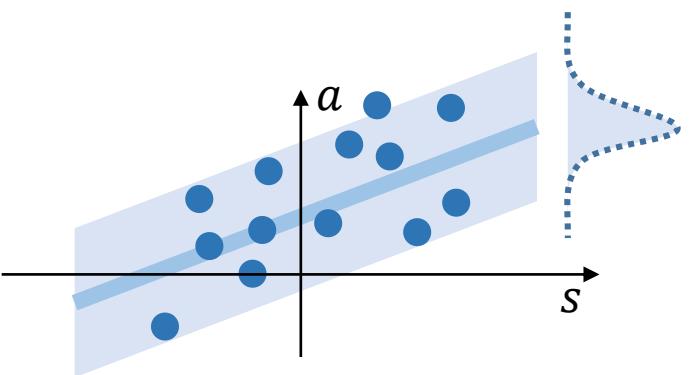
Time-Action Space



State-Action Space

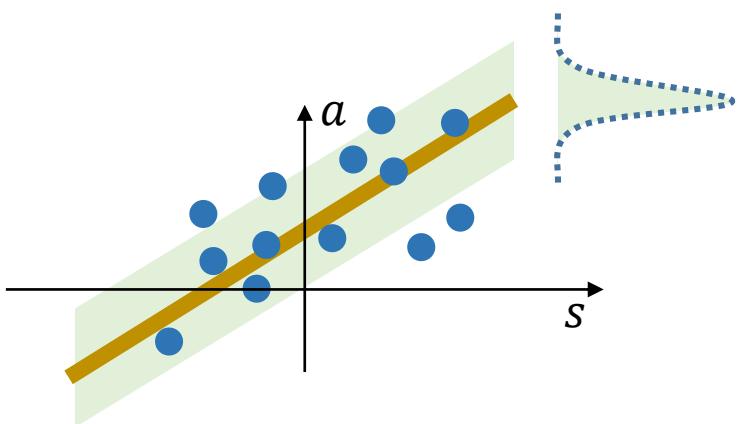


Policy Update

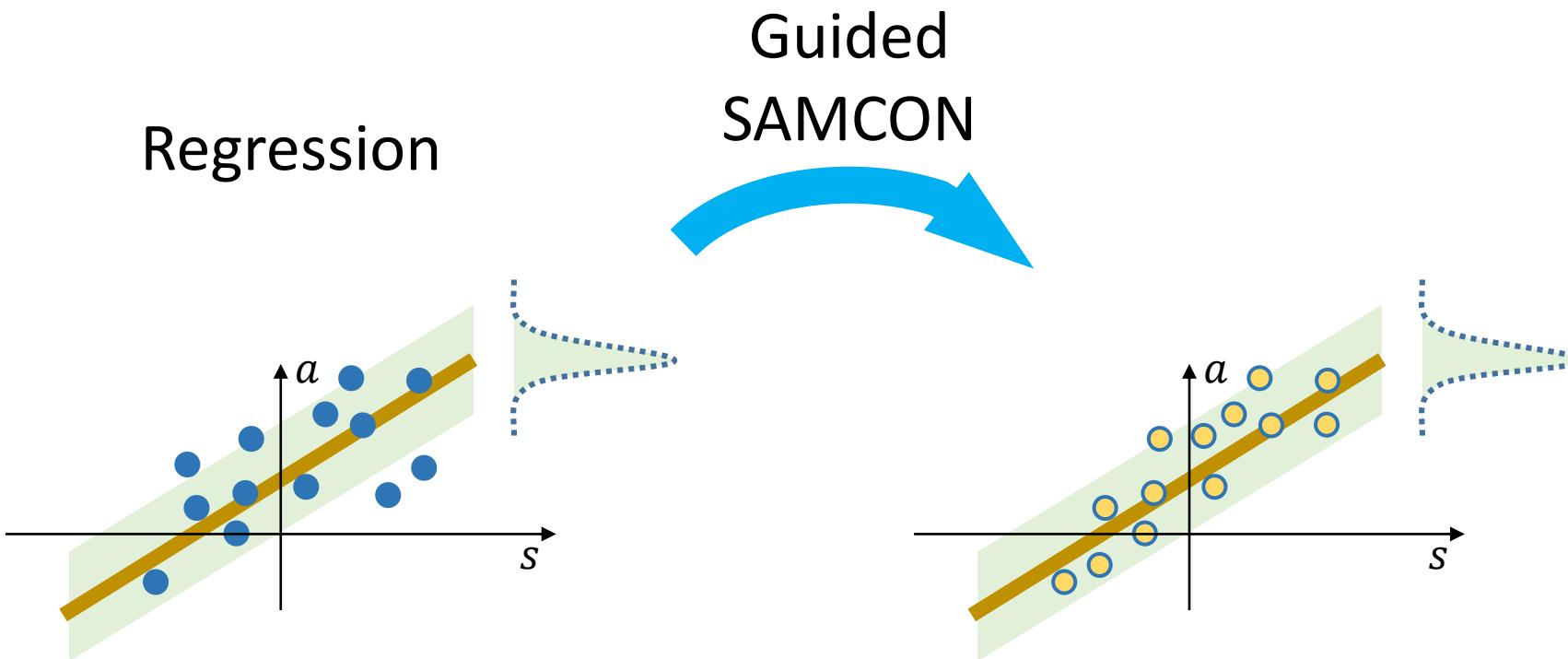


Policy Update

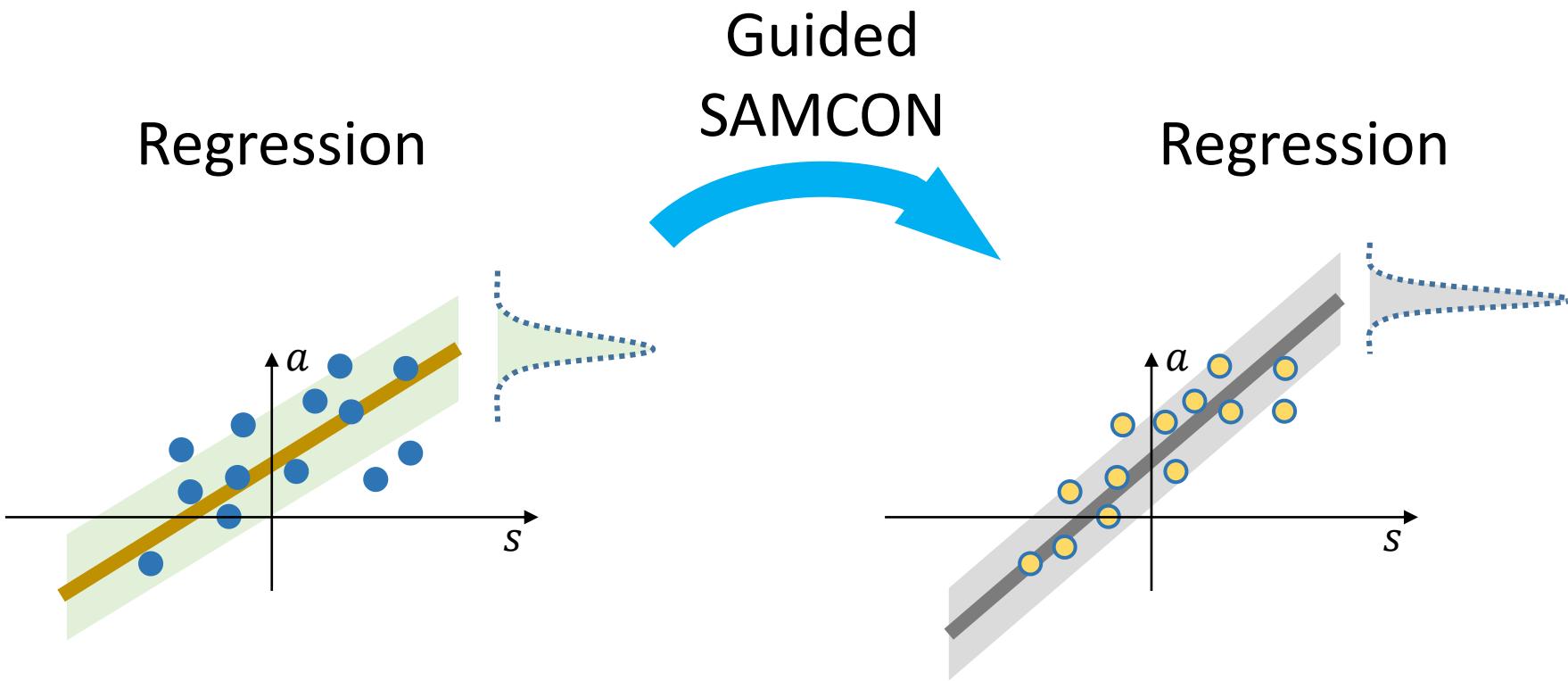
Regression



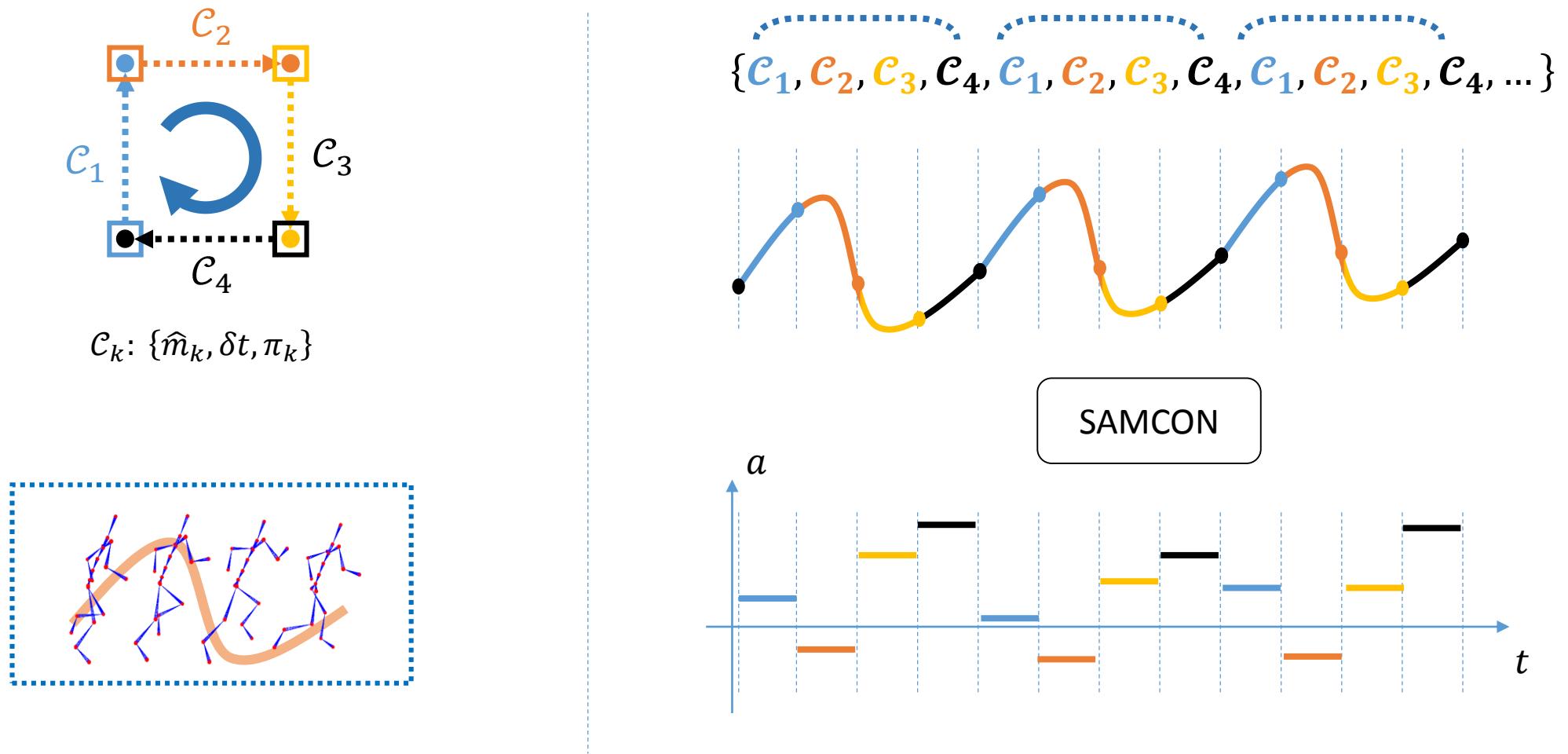
Guided Learning Iterations



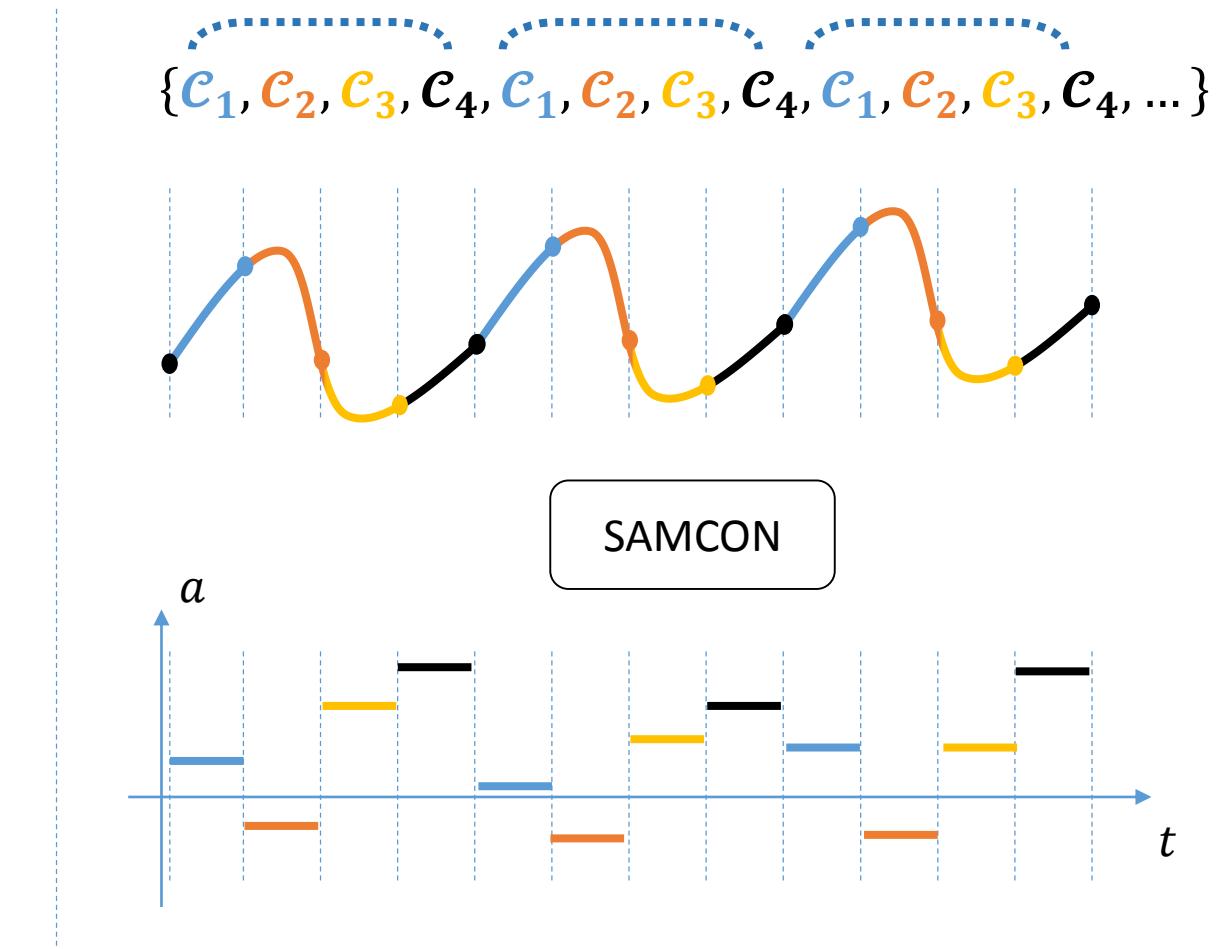
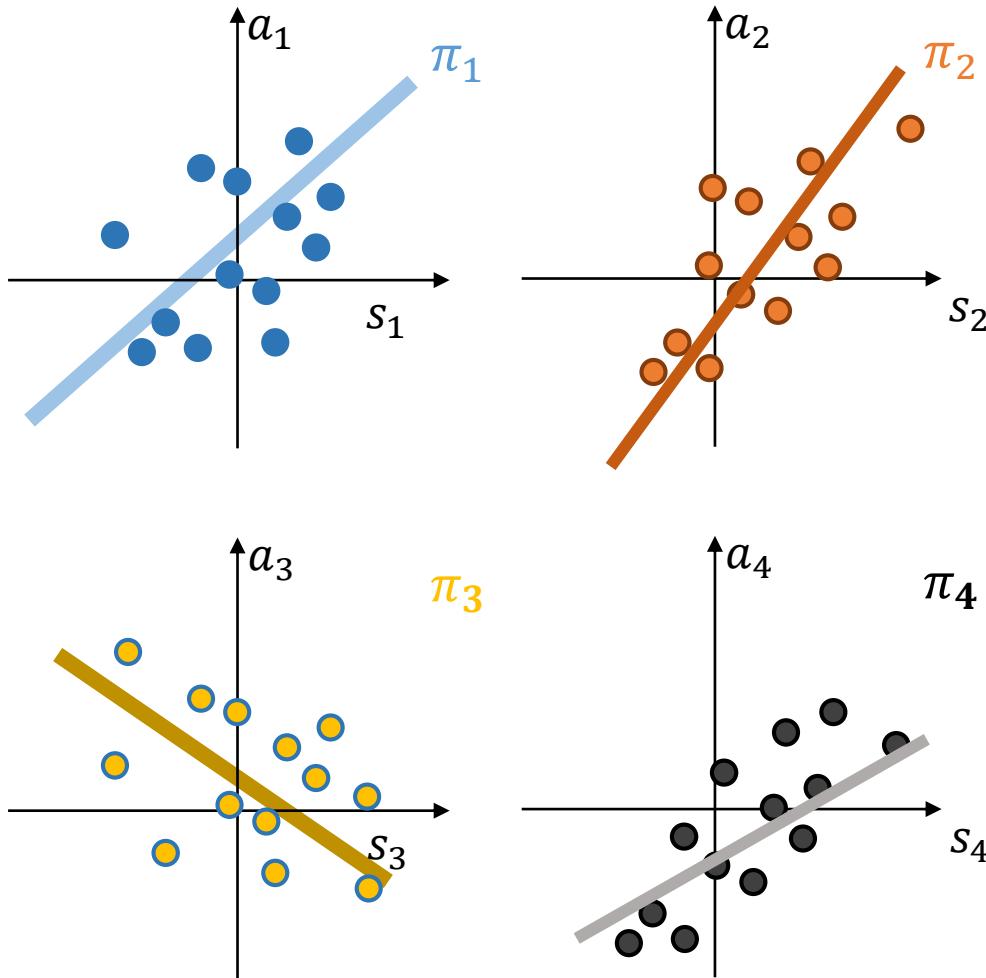
Guided Learning Iterations



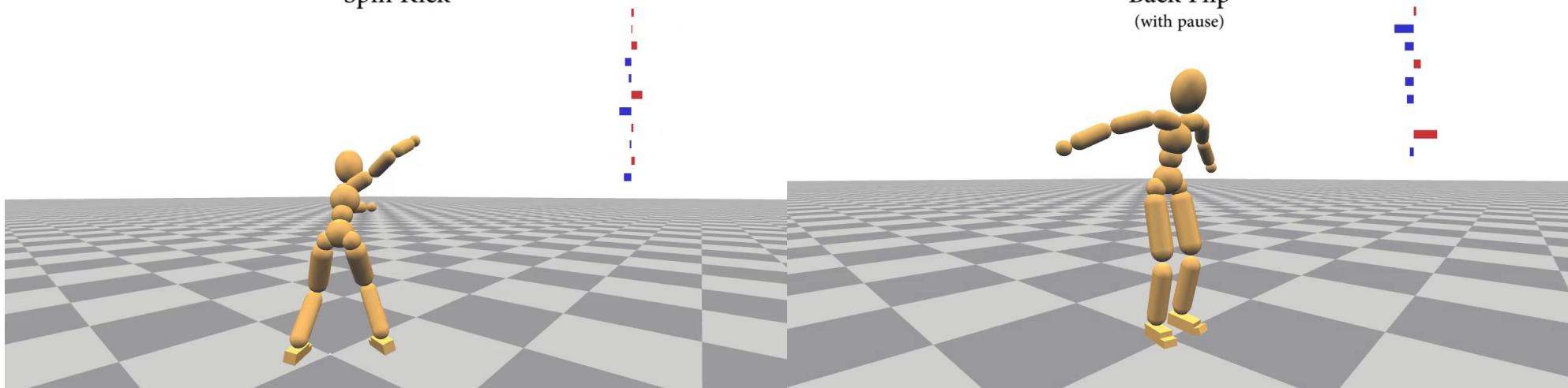
Example: Cyclical Motion



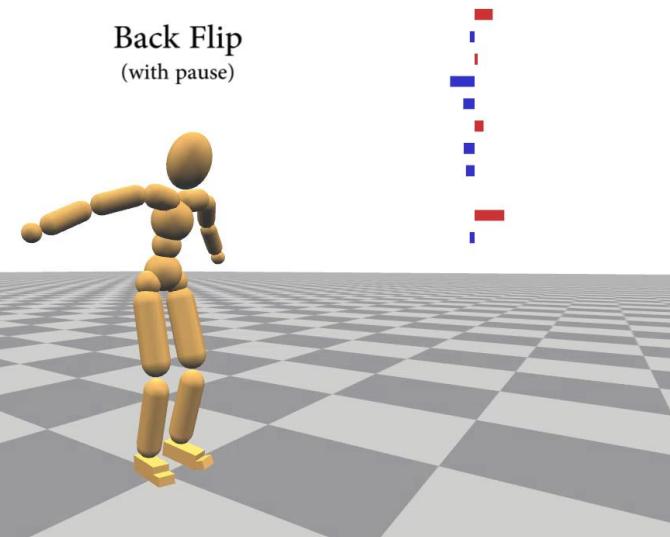
Example: Cyclical Motion



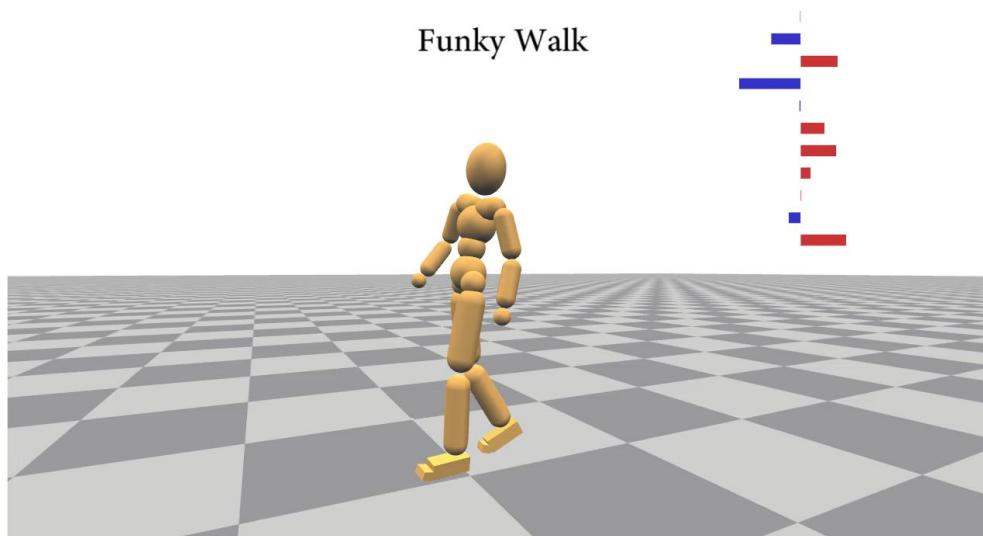
Spin Kick



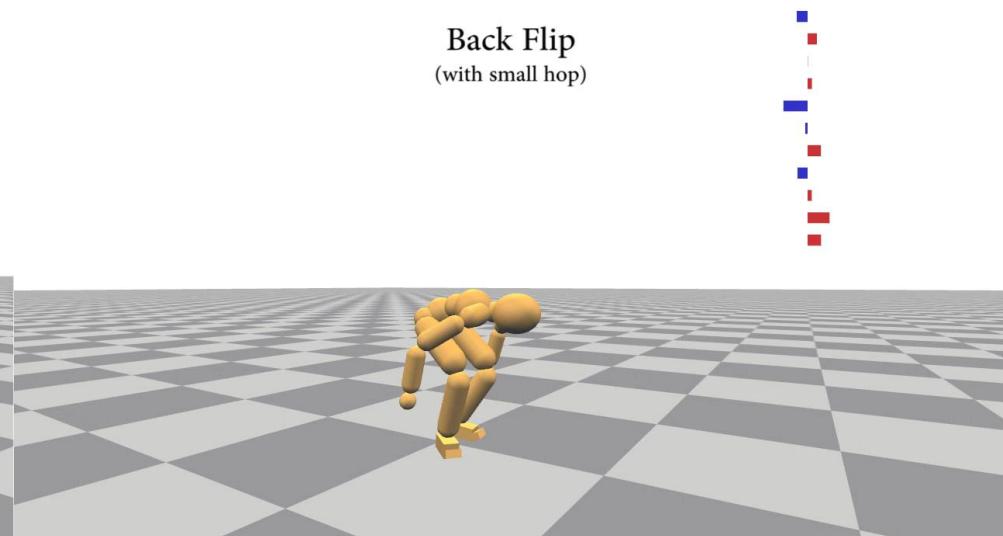
Back Flip
(with pause)



Funky Walk

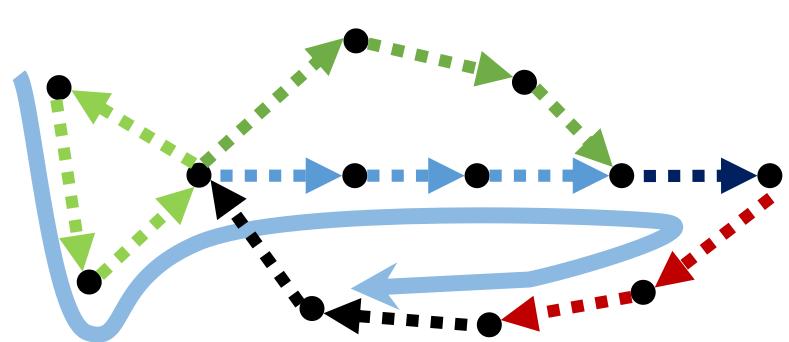


Back Flip
(with small hop)

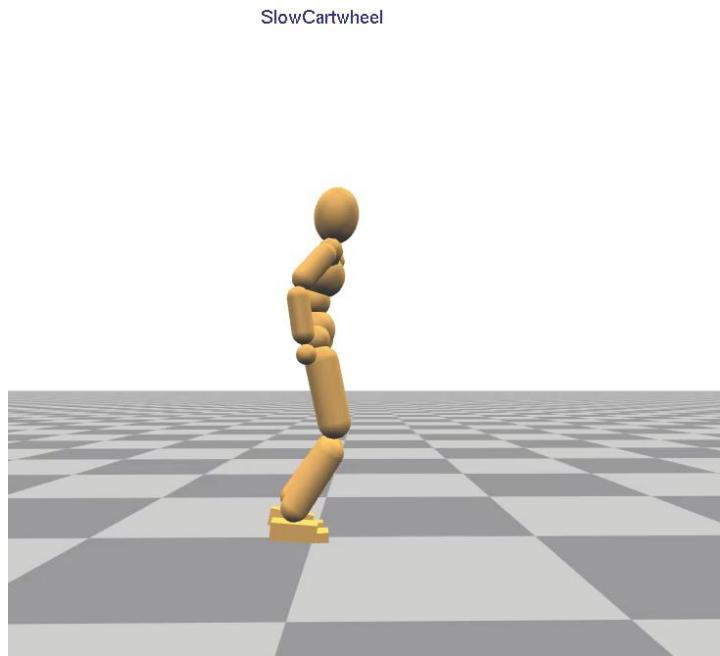


Control Graph

A graph whose nodes are control fragments



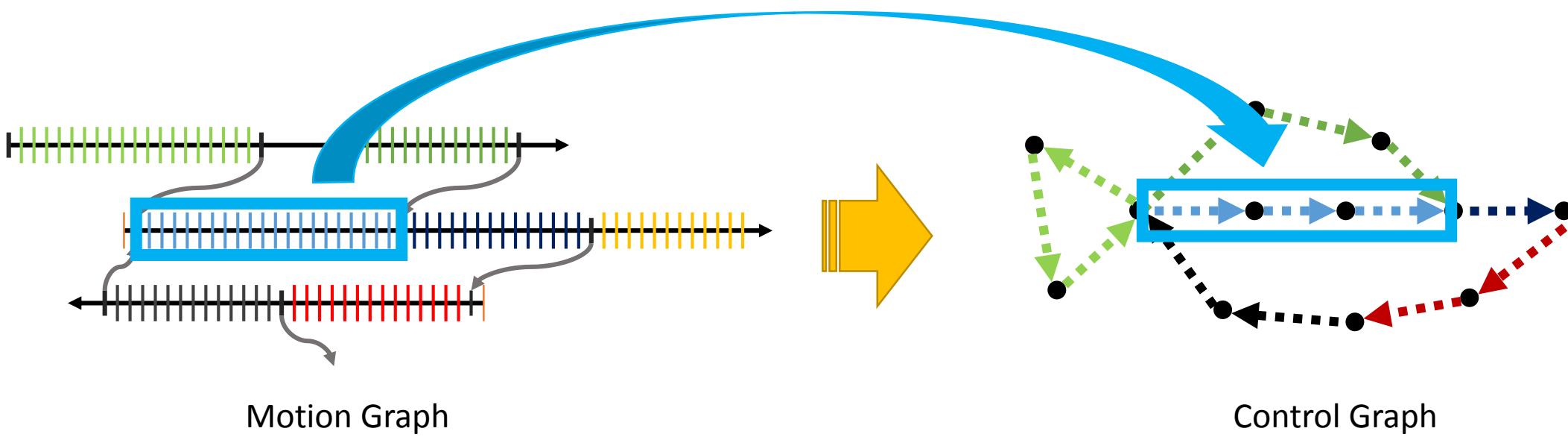
Control Graph



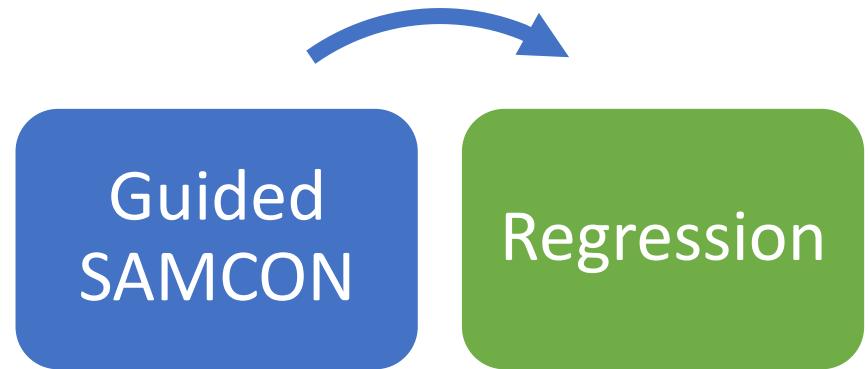
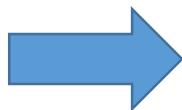
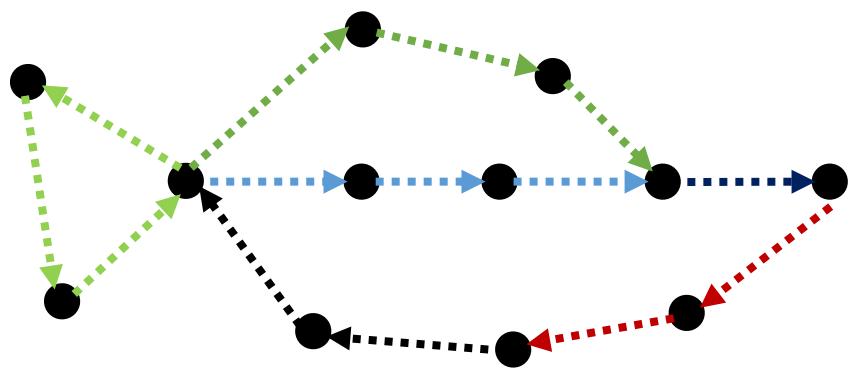
Control Graph

A graph whose nodes are control fragments

Converted from a motion graph



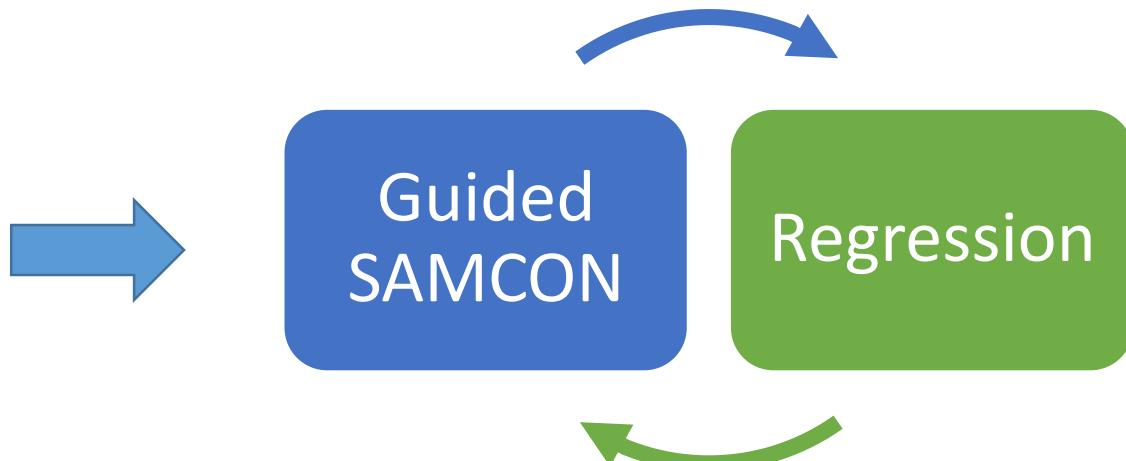
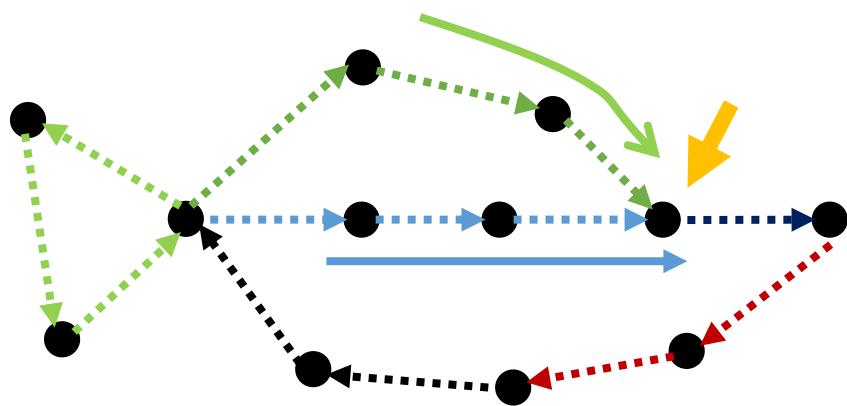
Learning of Control Graphs



Random Walk (\mathcal{W}):

$$\{\mathcal{C}_1, \mathcal{C}_2, \mathcal{C}_3, \mathcal{C}_1, \mathcal{C}_2, \mathcal{C}_3, \mathcal{C}_4, \mathcal{C}_5, \mathcal{C}_6, \dots\}$$

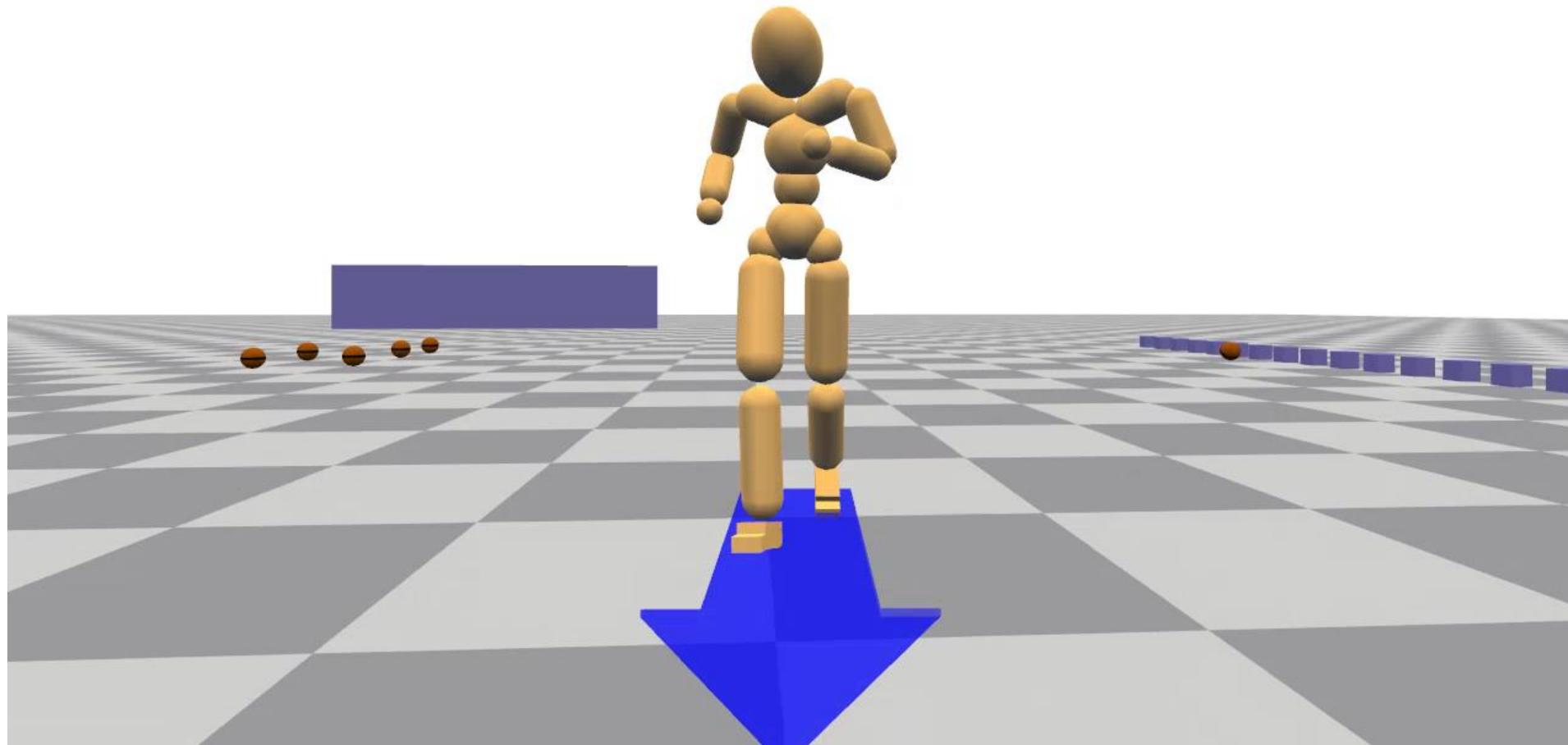
Learning of Control Graphs

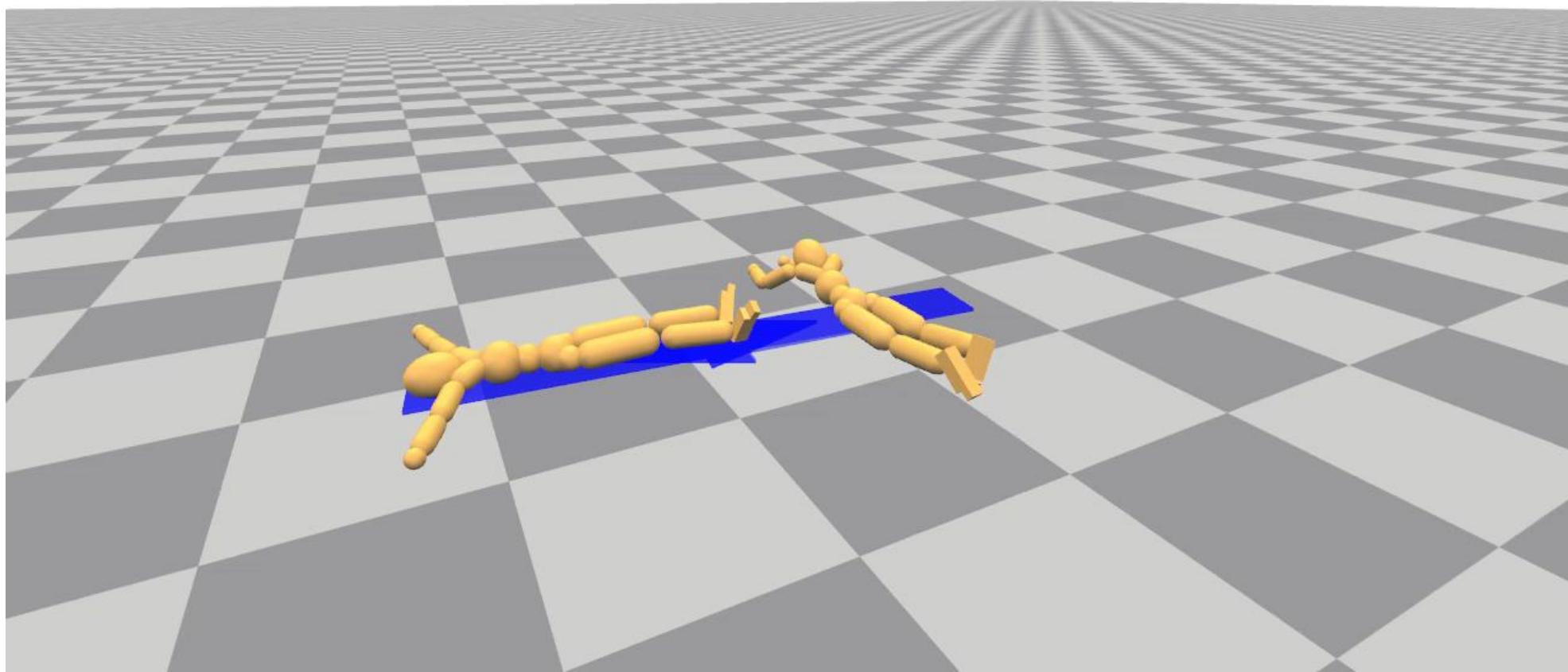


Random Walk (\mathcal{W}):

$$\{\mathcal{C}_1, \mathcal{C}_2, \mathcal{C}_3, \mathcal{C}_1, \mathcal{C}_2, \mathcal{C}_3, \mathcal{C}_4, \mathcal{C}_5, \mathcal{C}_6, \dots\}$$

SlowRun





Performance

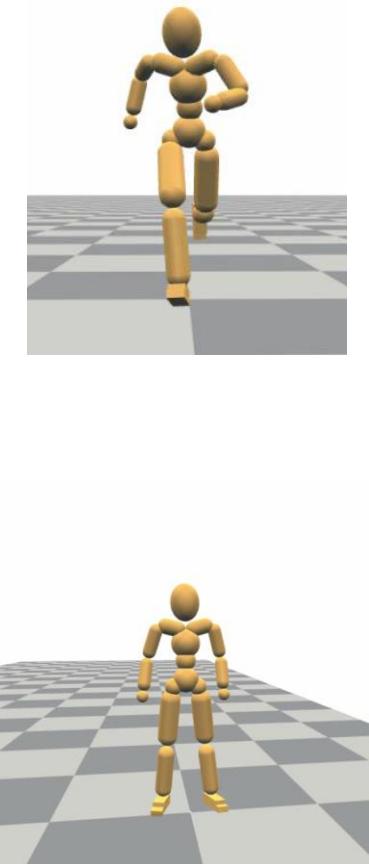
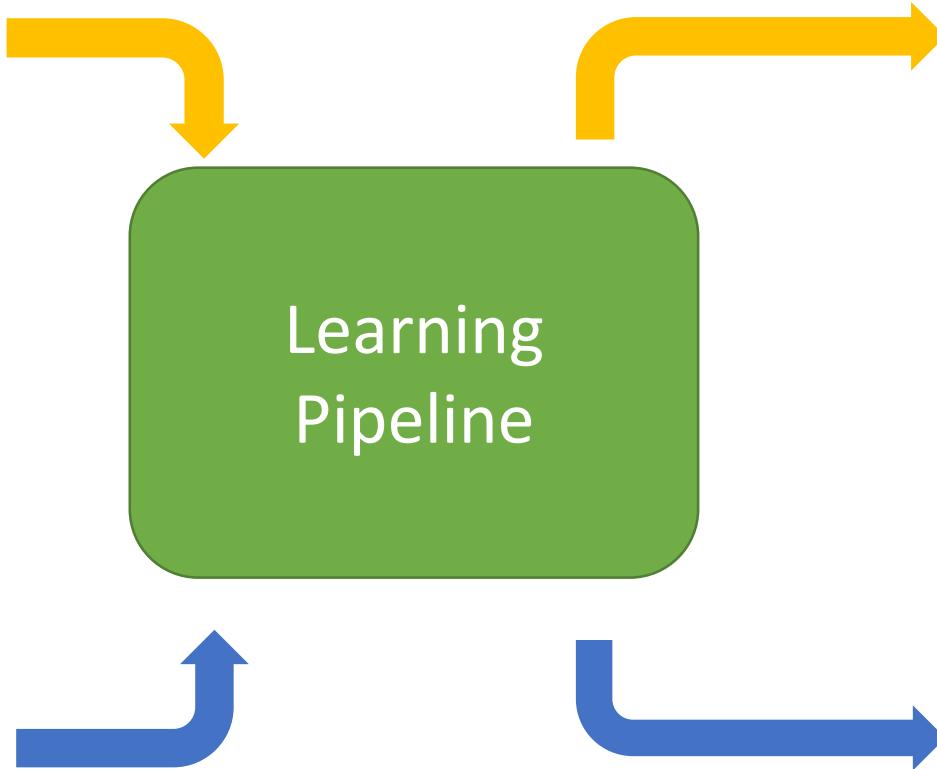
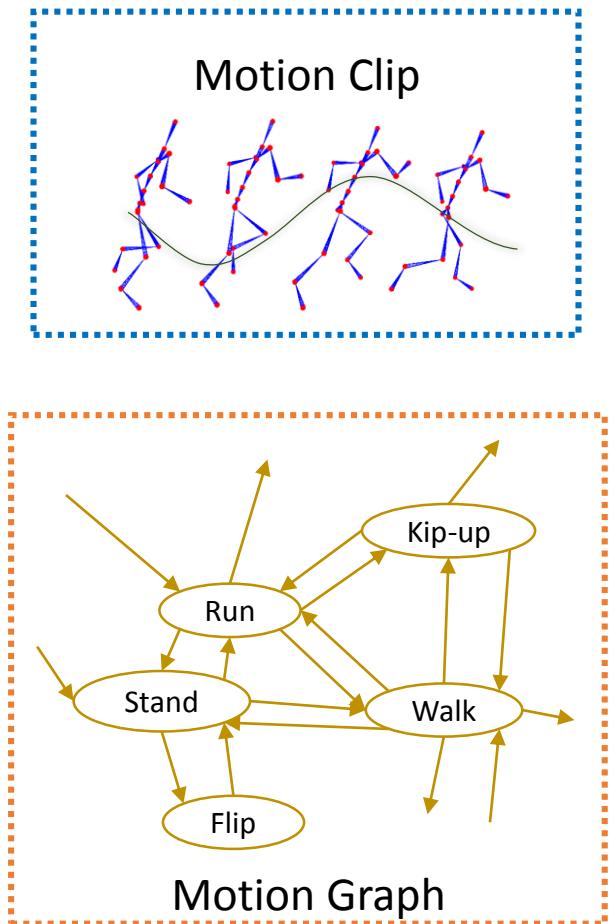
Offline learning

- 1 second reference motion -> \approx 1 hour learning
- 20-core computer

Runtime

- >10x realtime
- ODE, time step: 5ms

Conclusion



Limitations & Future Work

Active human-object interaction

- basketball, soccer

Multi-character interaction

- dancing, boxing, martial arts

Motion Planning