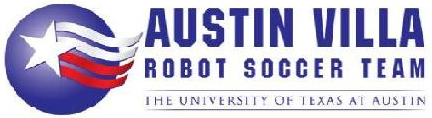

A Black-Box Approach to Sim-to-Real Transfer

Siddharth Desai, Haresh Karnan, Ishan Durugkar,
Josiah Hanna, Garrett Warnell, Peter Stone

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ROBOT SOCCER TEAM
THE UNIVERSITY OF TEXAS AT AUSTIN

1. **The Sim-To-Real Problem**
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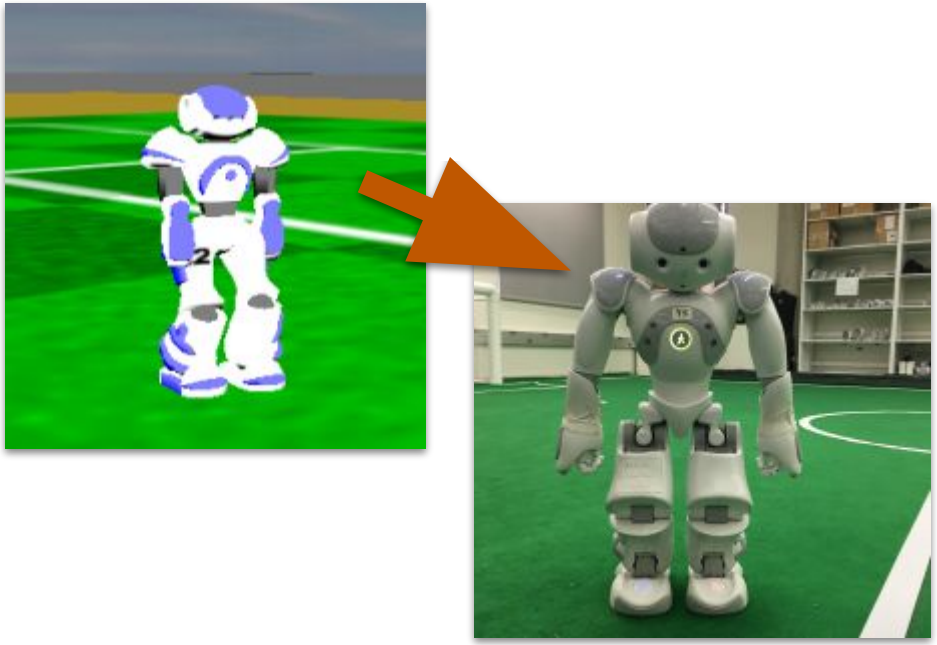
4. GAT in Stochastic Domains (SGAT)
5. Questions?

The Sim-to-Real Problem

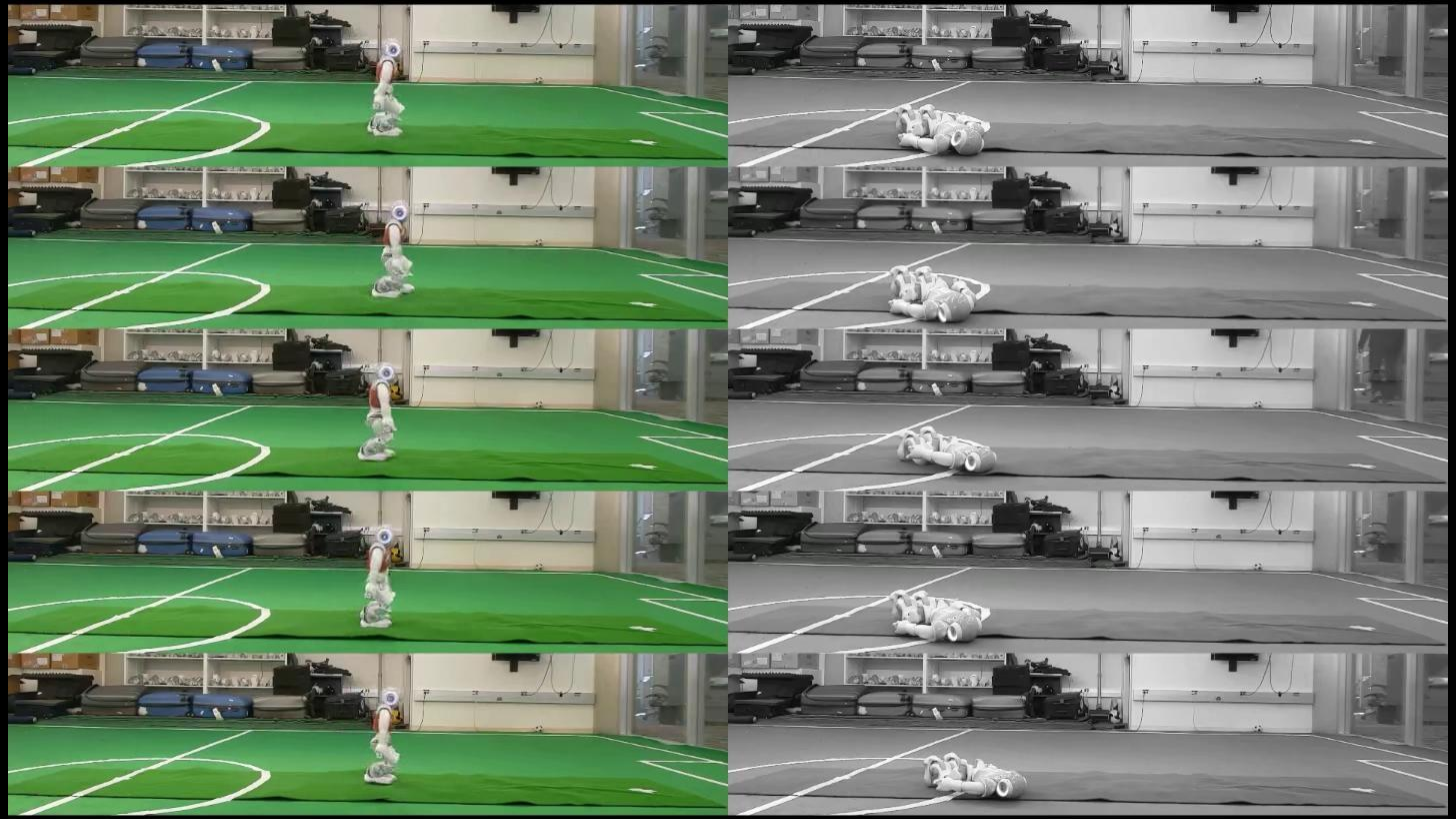


Real world training is

- Expensive
- Time Consuming
- Potentially unsafe

SGAT

GAT



Our approach learns policies that are more robust to stochastic environments

Hanna, Josiah P. and Peter Stone. “Grounded Action Transformation for Robot Learning in Simulation.” *AAAI* (2017).

Sim-to-Real Paradigms

Learn a *robust* policy by training in multiple simulators

-Deploy directly in real world

-Tradeoff between generalization and performance

Robustness Approach

Train partially in simulation

-Finish training in real world

-Still prone to overfitting in simulator

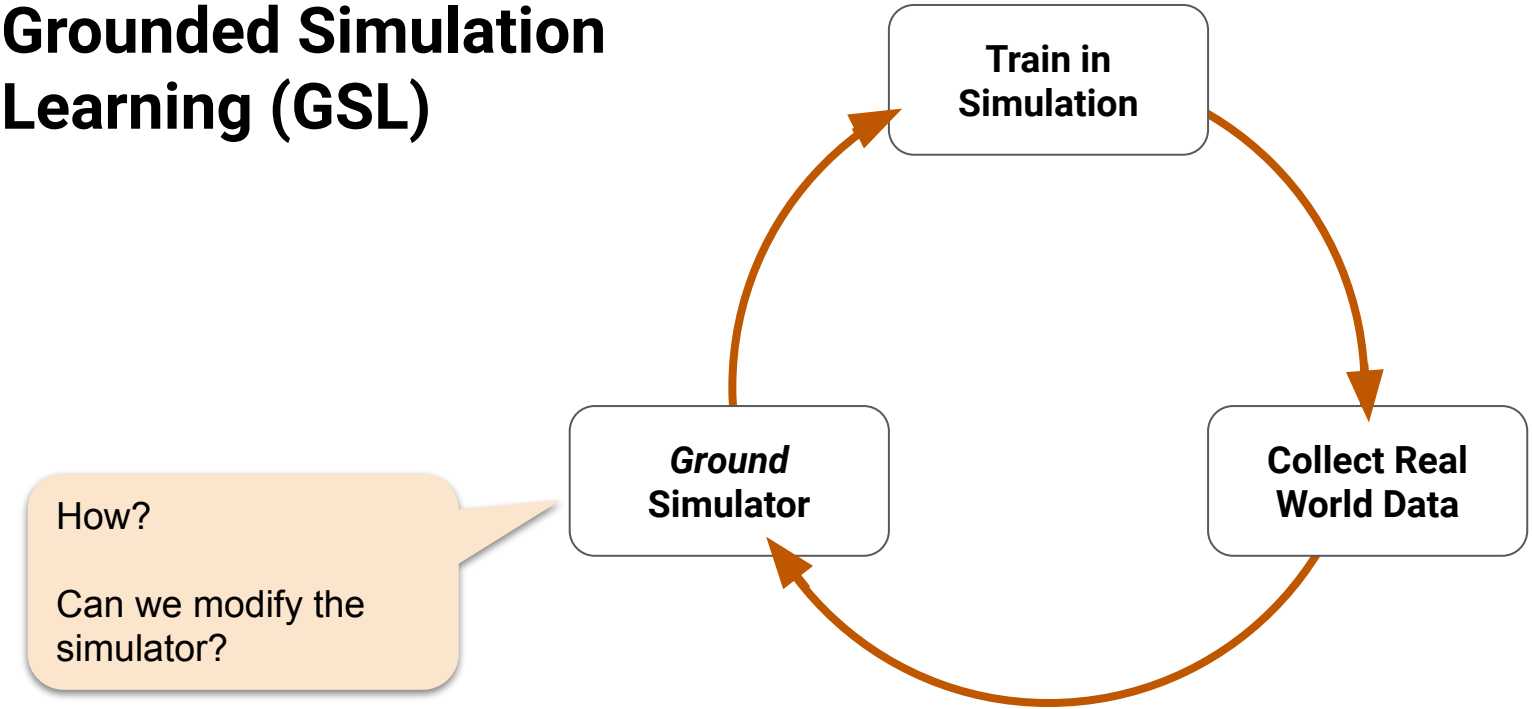
Bootstrapping Approach

Use a little real world data to *ground* simulator

-Iteratively improve simulator until desired performance is reached

Grounding Approach

Grounded Simulation Learning (GSL)



A. Farchy, S. Barrett, P. MacAlpine, and P. Stone, "Humanoid robots learning to walk faster: From the real world to simulation and back," in Proc. of 12th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS), May 2013.

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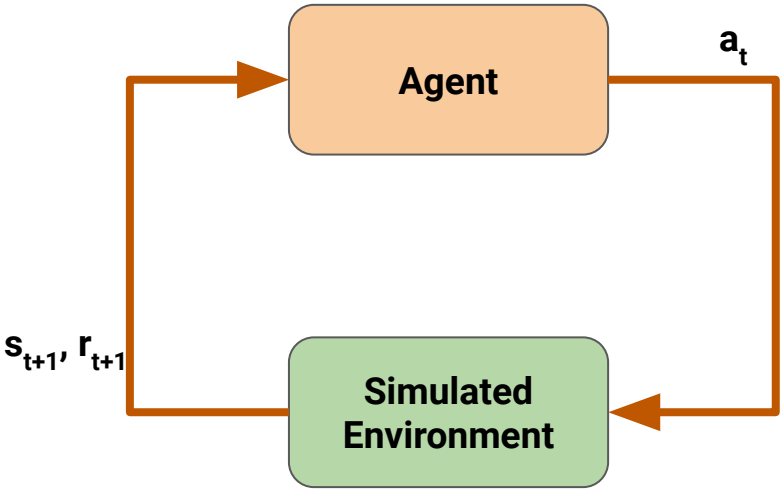
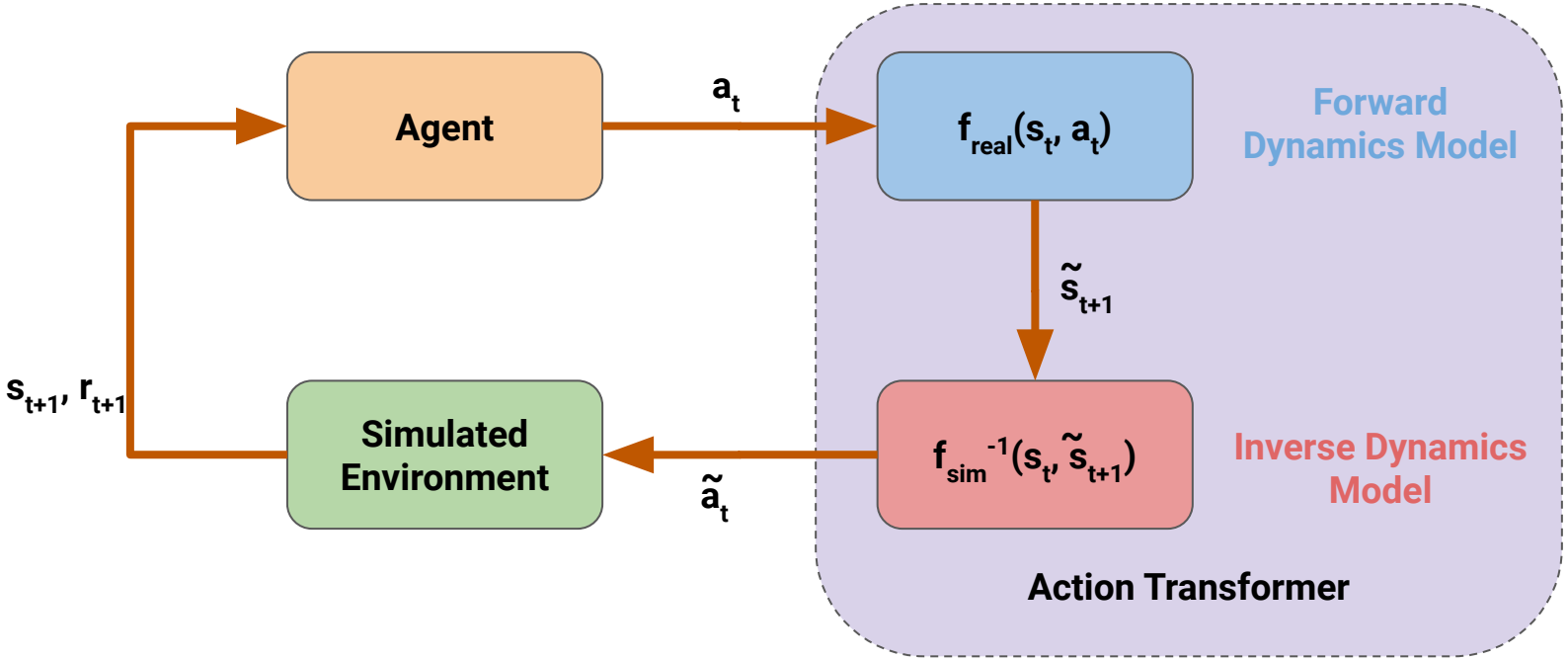
Reinforcement Learning



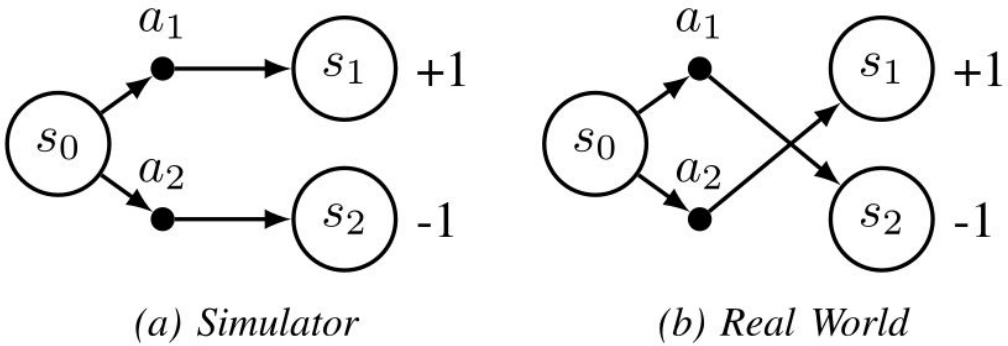
J. Hanna and P. Stone, "Grounded action transformation for robot learning in simulation," in Proceedings of the 31st AAAI Conference on Artificial Intelligence (AAAI), February 2017.

Grounded Action Transformation (GAT)

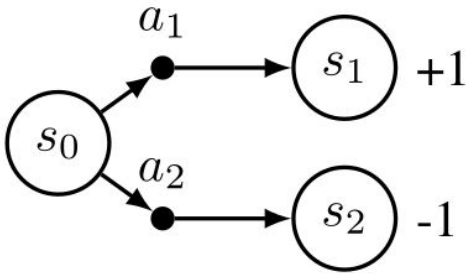


J. Hanna and P. Stone, "Grounded action transformation for robot learning in simulation," in Proceedings of the 31st AAAI Conference on Artificial Intelligence (AAAI), February 2017.

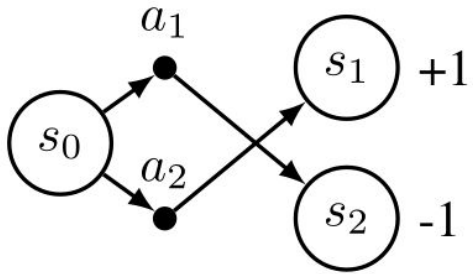
GAT Example



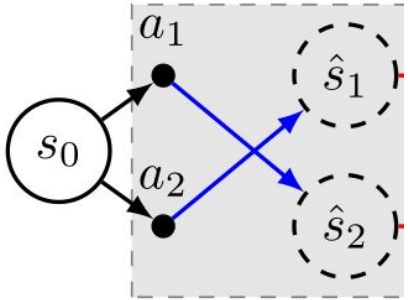
GAT Example



(a) Simulator



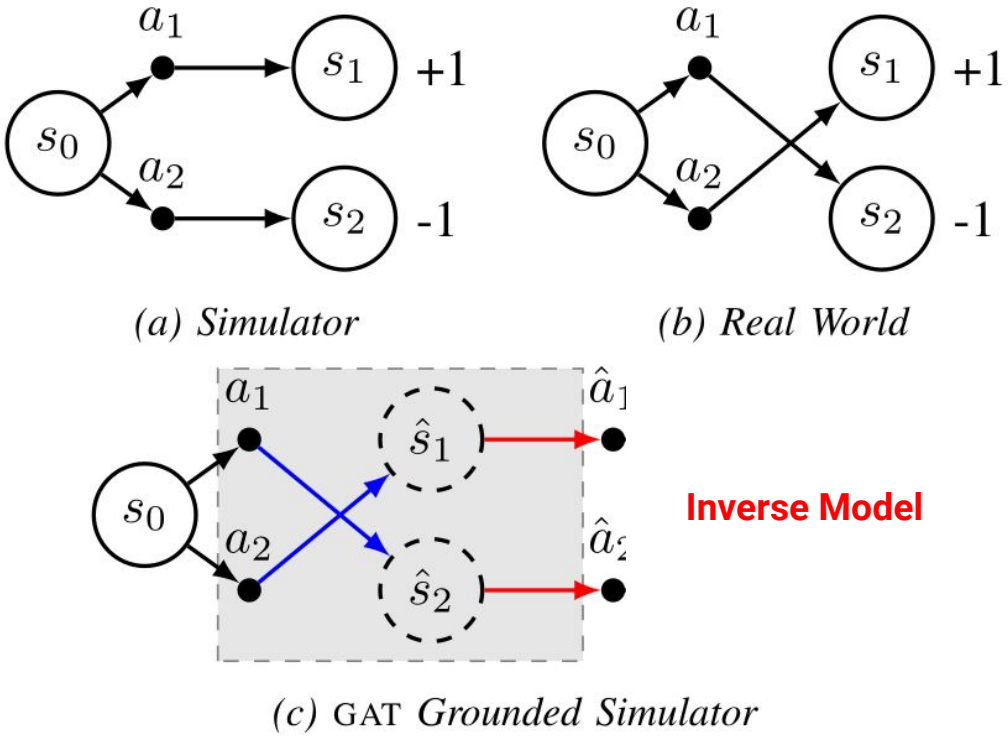
(b) Real World



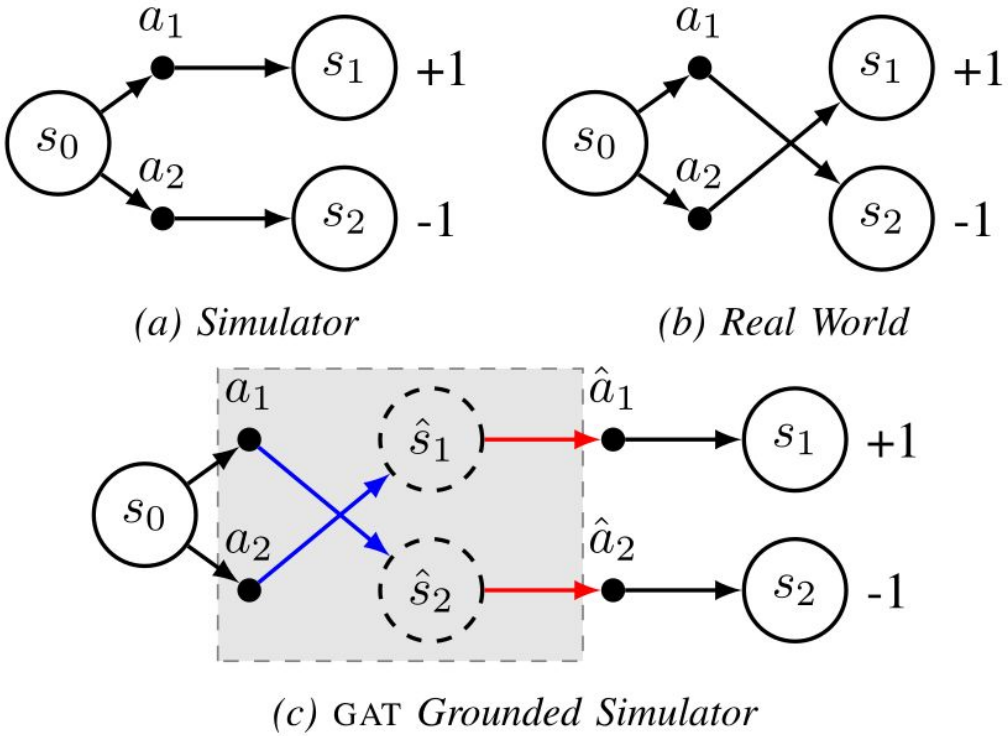
Forward Model

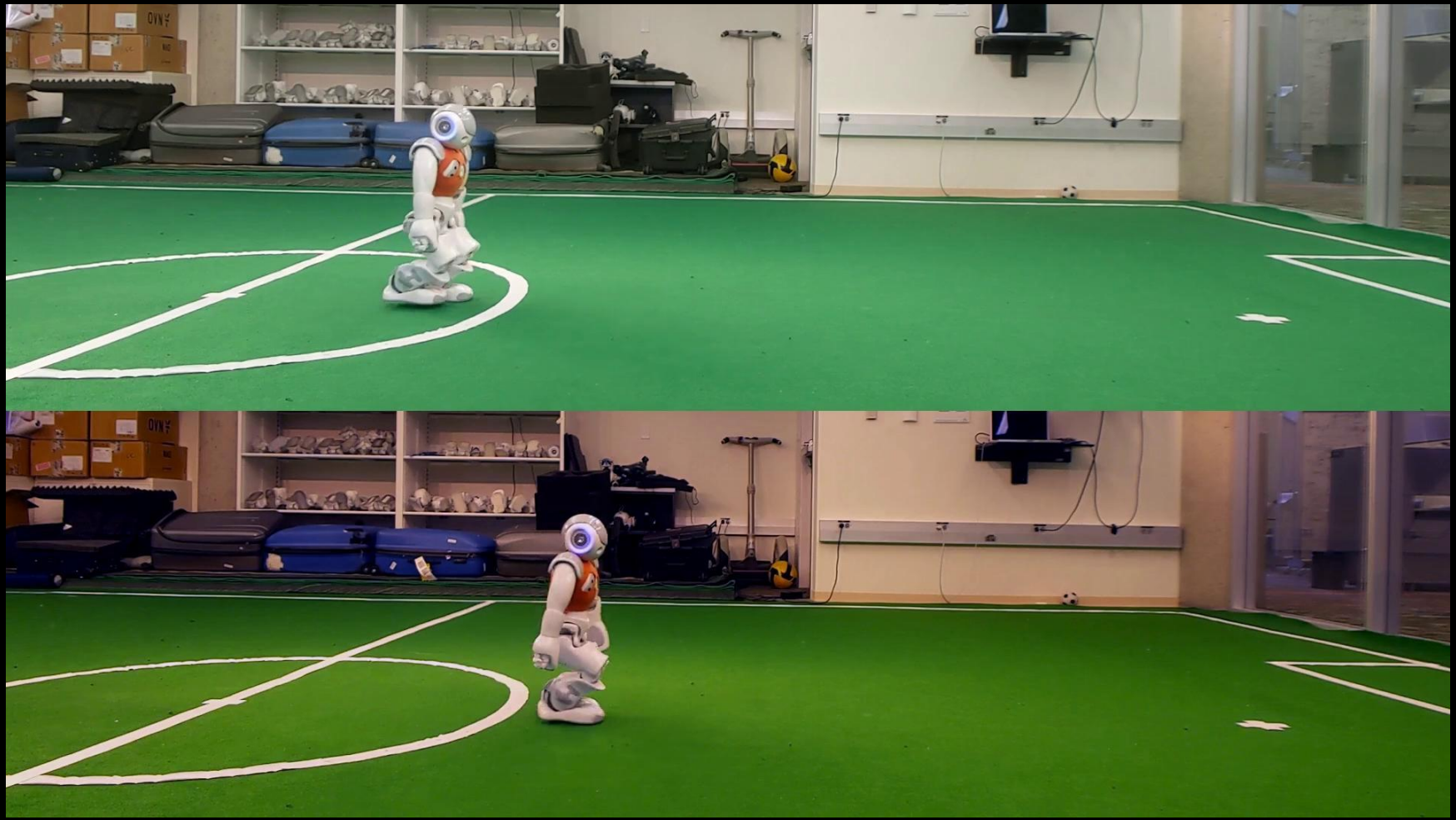
(c) GAT *Grounded Simulator*

GAT Example


a_1
s_1
+1
s_0
a_2
s_2
-1
(a) Simulator
a_1
s_1
+1
s_0
a_2
s_2
-1
(b) Real World
a_1
$\hat{a}_1$
$\hat{s}_1$
s_0
a_2
$\hat{a}_2$
$\hat{s}_2$
Inverse Model
(c) GAT Grounded Simulator

GAT Example


a_1
s_1
+1
s_0
a_2
s_2
-1
(a) Simulator
a_1
s_1
+1
s_0
a_2
s_2
-1
(b) Real World
a_1
$\hat{s}_1$
$\hat{a}_1$
s_1
+1
s_0
a_2
$\hat{s}_2$
$\hat{a}_2$
s_2
-1
(c) GAT Grounded Simulator



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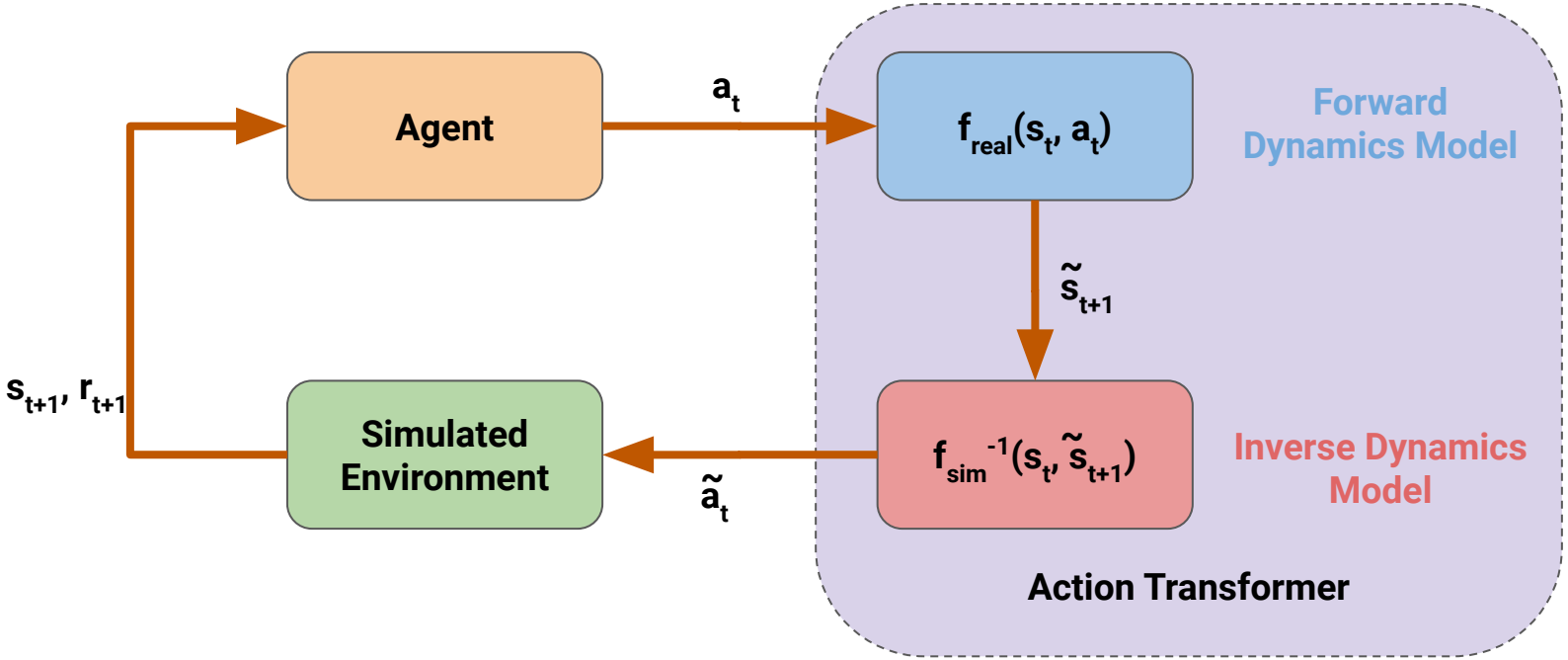
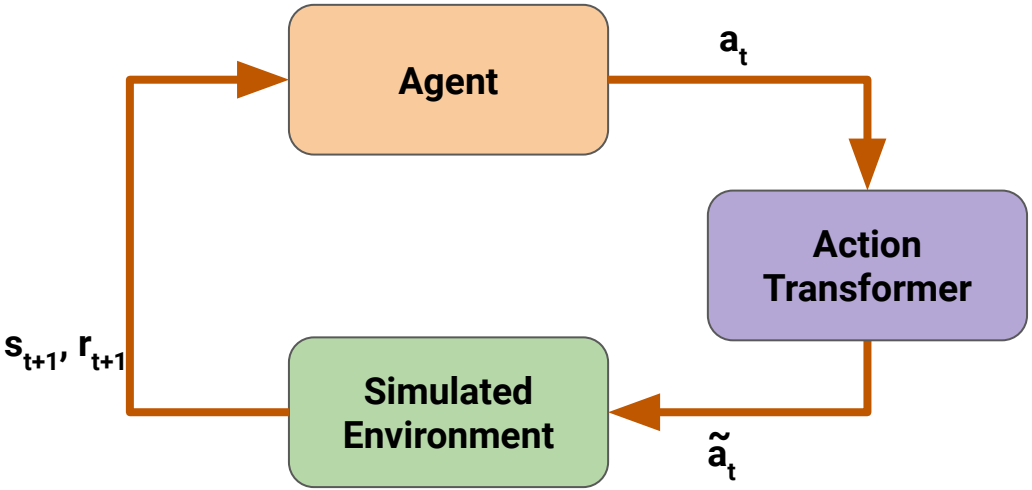
Reinforced Grounded Action Transformation (RGAT)

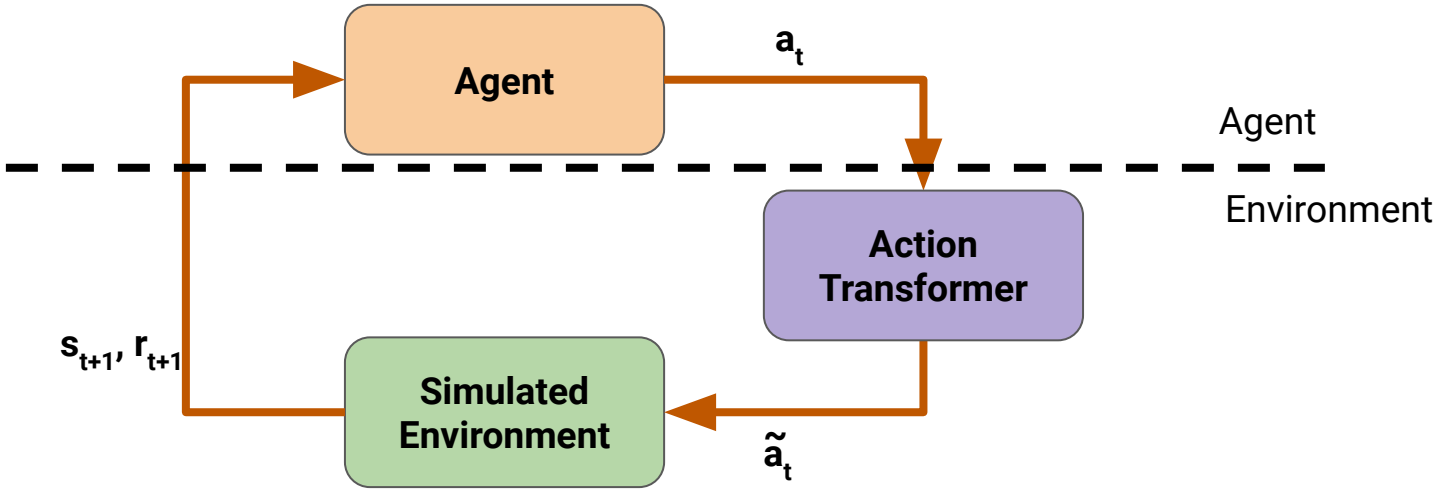


Reinforced Grounded Action Transformation (RGAT)

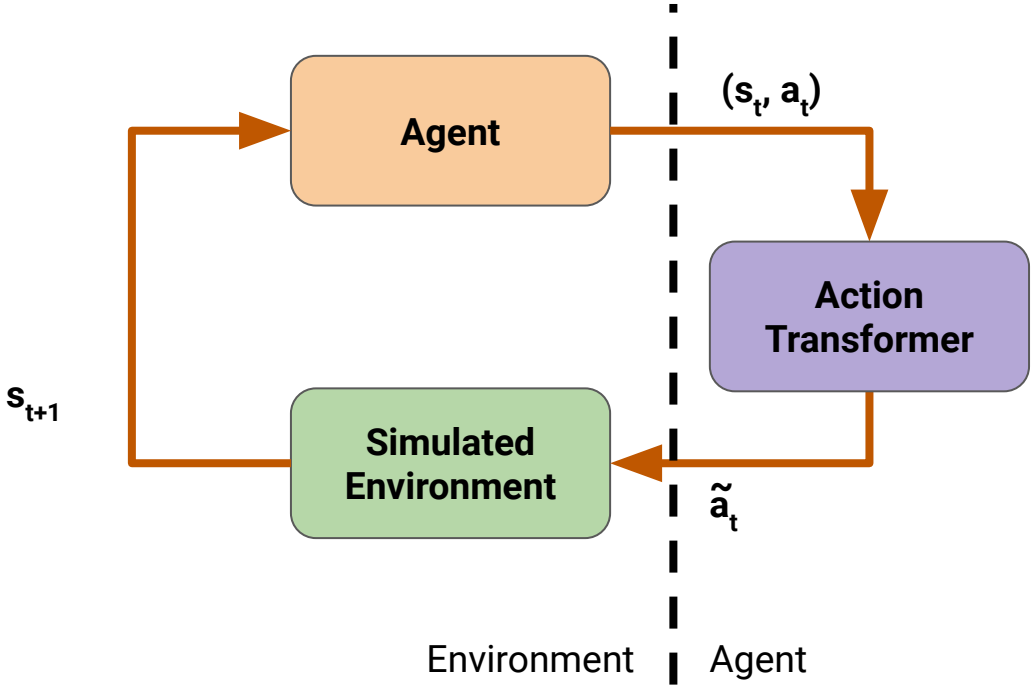


Learning the action transformation function end-to-end makes it easier to learn small changes

Reinforced Grounded Action Transformation (RGAT)

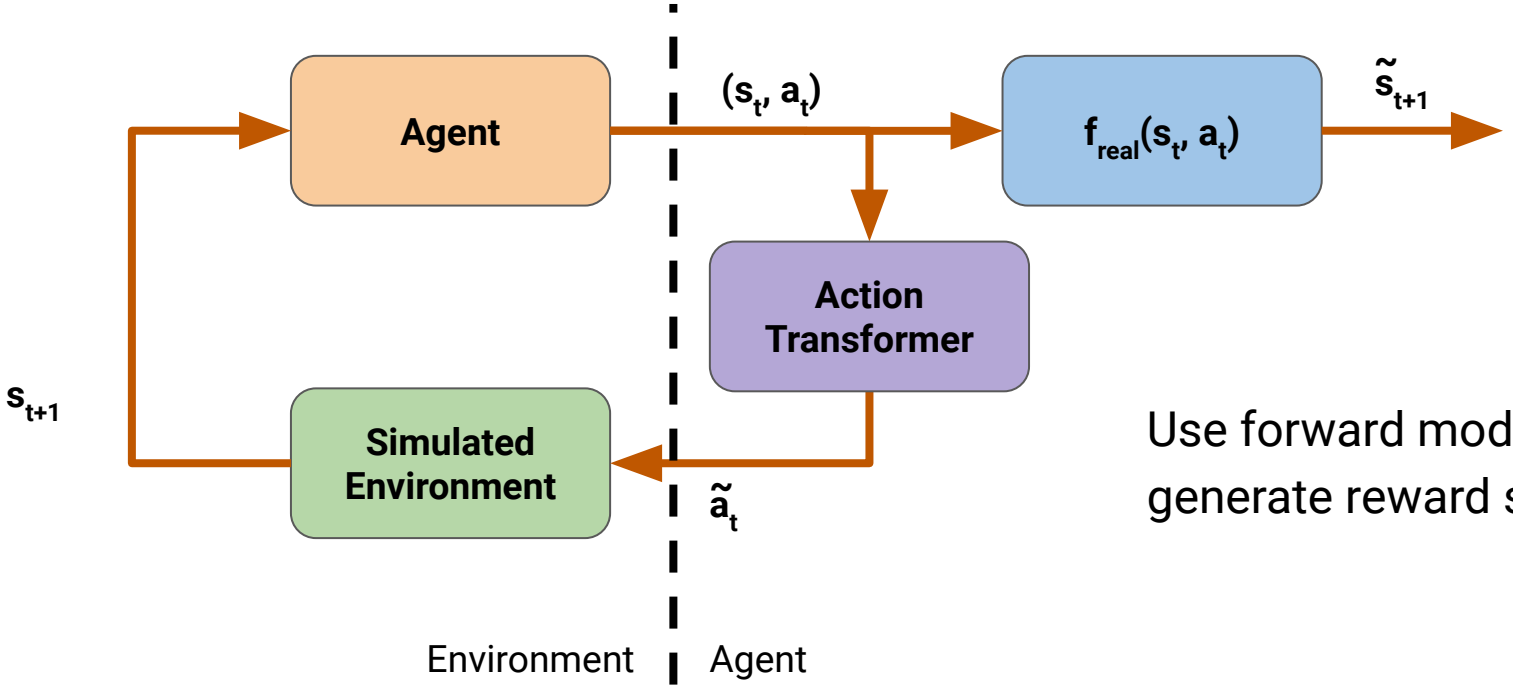


Reinforced Grounded Action Transformation (RGAT)



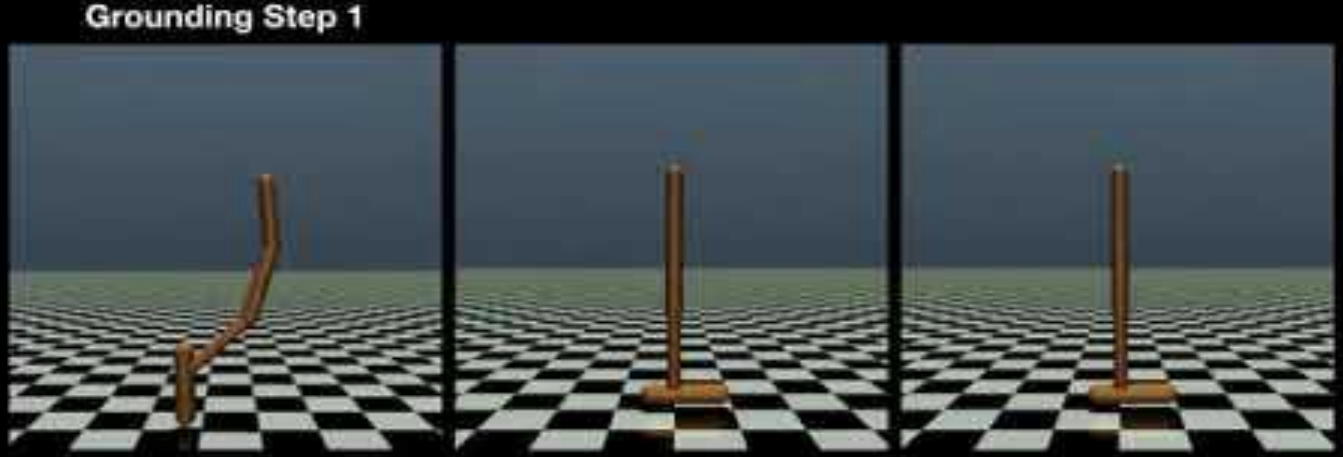
Treating the grounding step as a reinforcement learning problem matches the whole trajectory instead of individual transitions

Reinforced Grounded Action Transformation (RGAT)

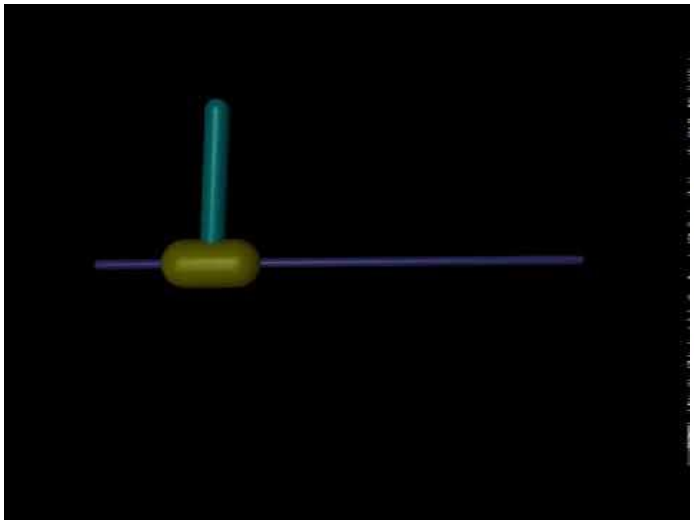


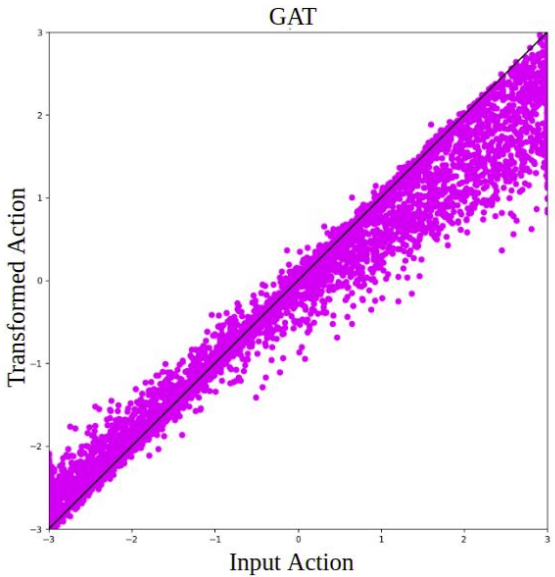
Use forward model to generate reward signal

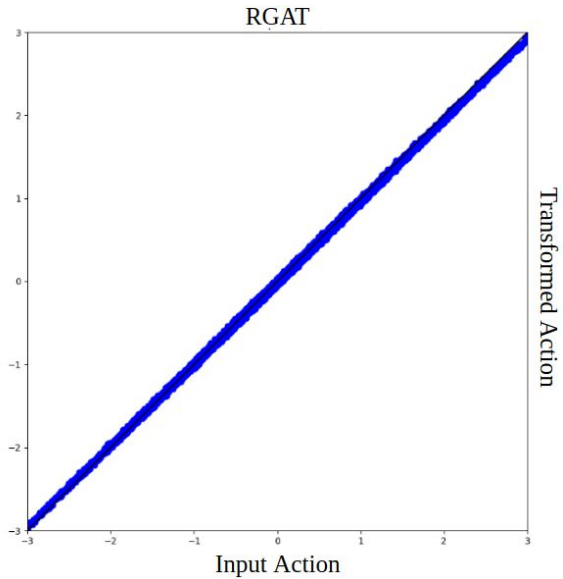
RGAT Policies Deployed on the "Real" World



Our method learns a good policy within two grounding steps




GAT
Transformed Action
Input Action


RGAT
Transformed Action
Input Action

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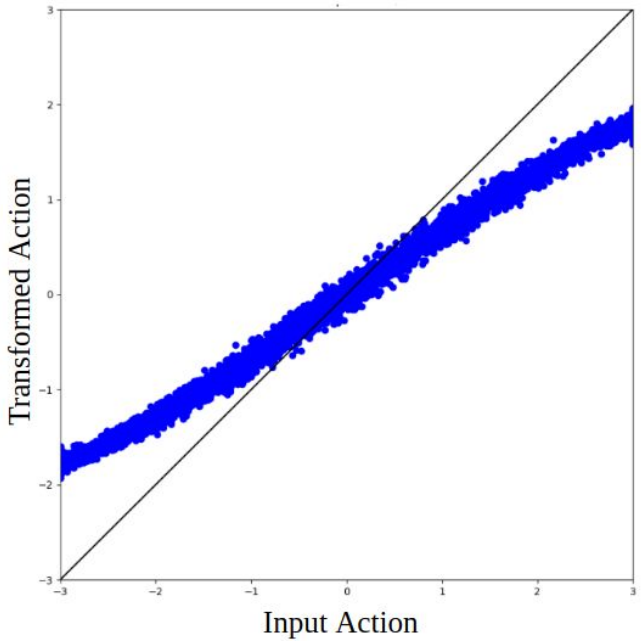
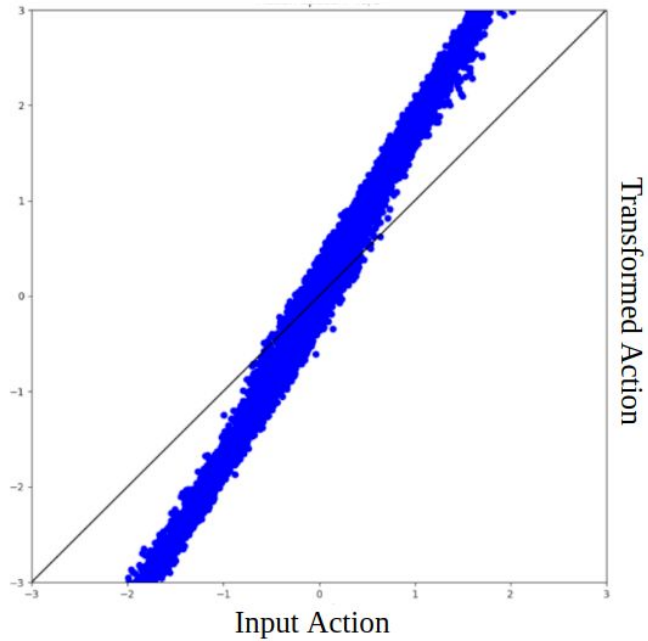
Transformed actions when the “real” pendulum is...

Heavier



Lighter



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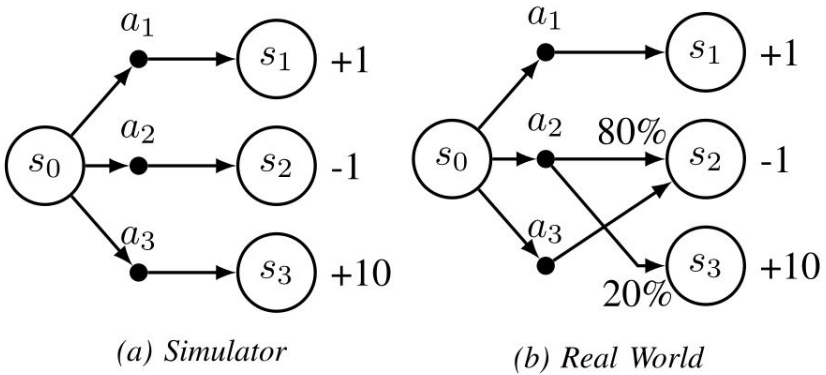
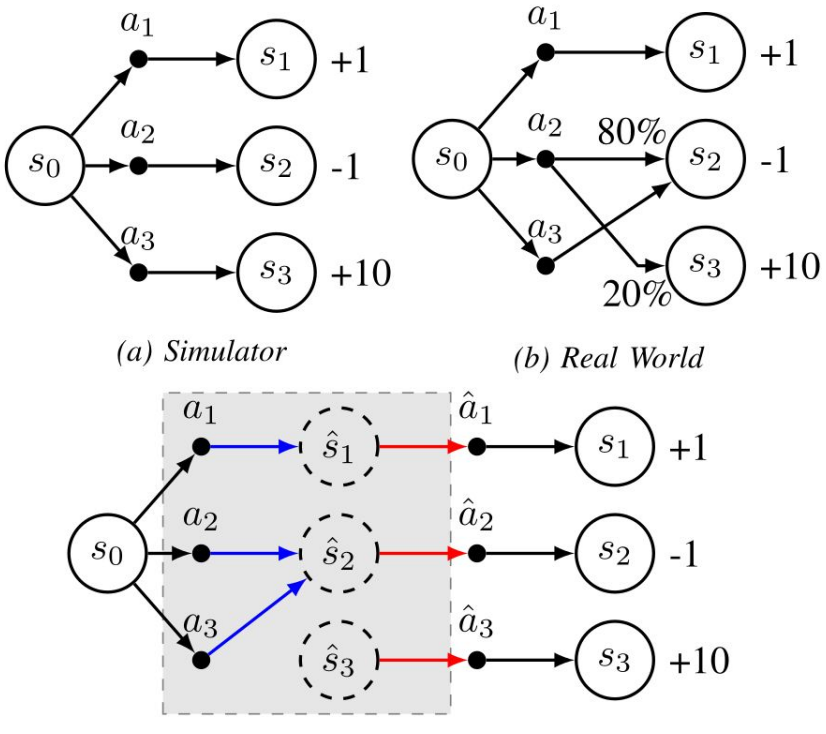
Stochastic Grounded Action Transformation (SGAT)



(a) Simulator *(b) Real World*

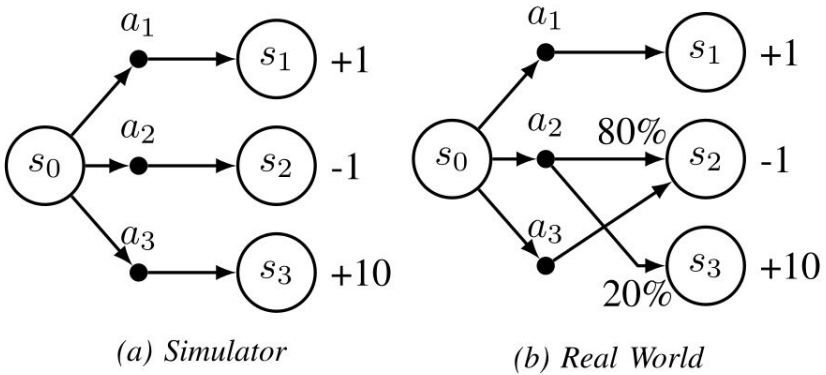
Stochastic Grounded Action Transformation (SGAT)

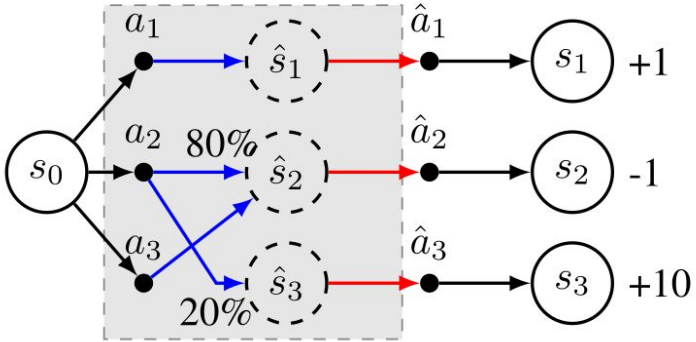


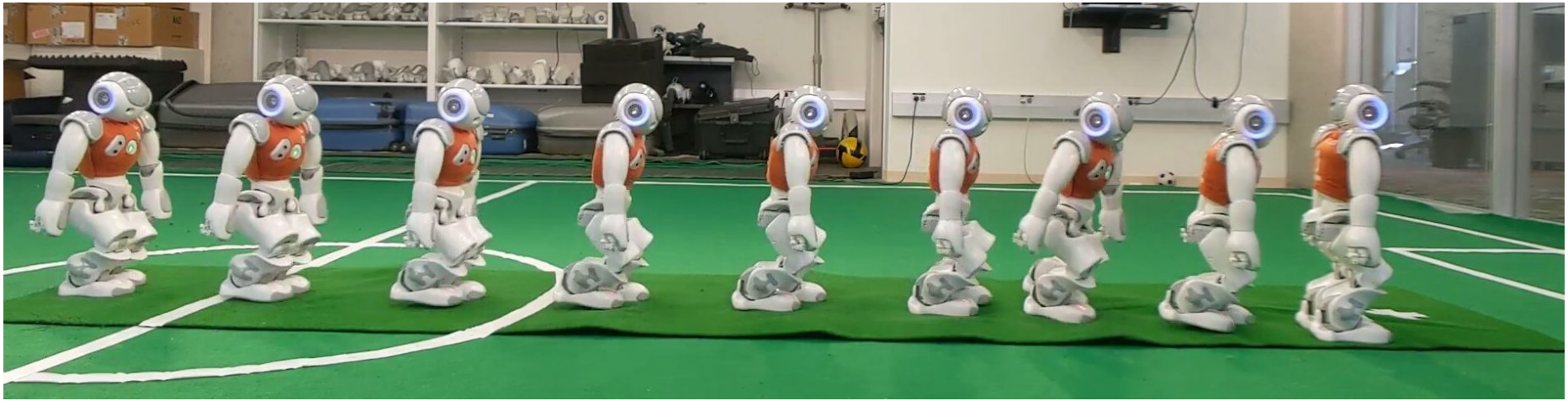
(a) Simulator *(b) Real World*

(c) GAT *Grounded Simulator*

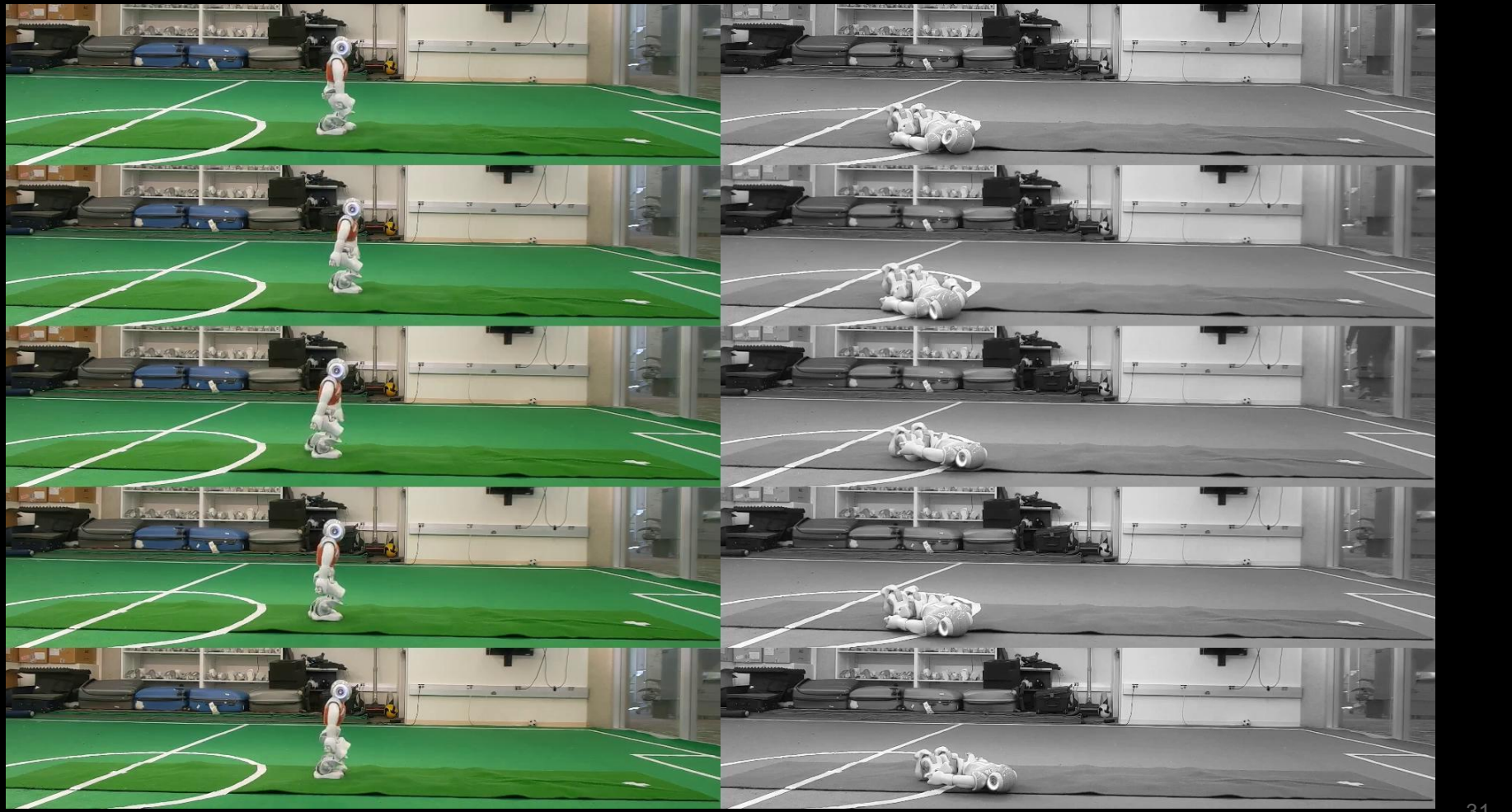
Stochastic Grounded Action Transformation (SGAT)



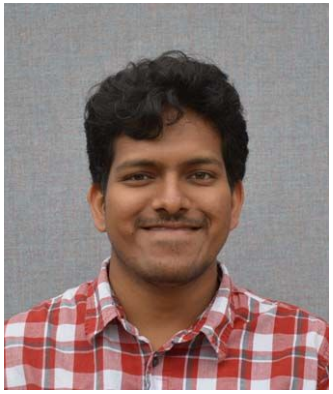




	Grounding Step 1		Grounding Step 2	
	Speed (cm/s)	Falls	Speed (cm/s)	Falls
GAT	15.7 ± 2.98	6/10	18.5 ± 3.63	10/10
SGAT	16.9 ± 0.678	**0/10**	18.0 ± 2.15	**1/10**



Haresh Karnan



Ishan Durugkar

Josiah Hanna

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Peter Stone

Thank You!

LARG
Learning Agents Research Group
The University of Texas at Austin

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