SIGGRAPH 2025
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PhysicsFC:

Learning User-Controlled Skills for a Physics-Based Football Player Controller

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MOTIVATION

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FC Online (FIFA series)

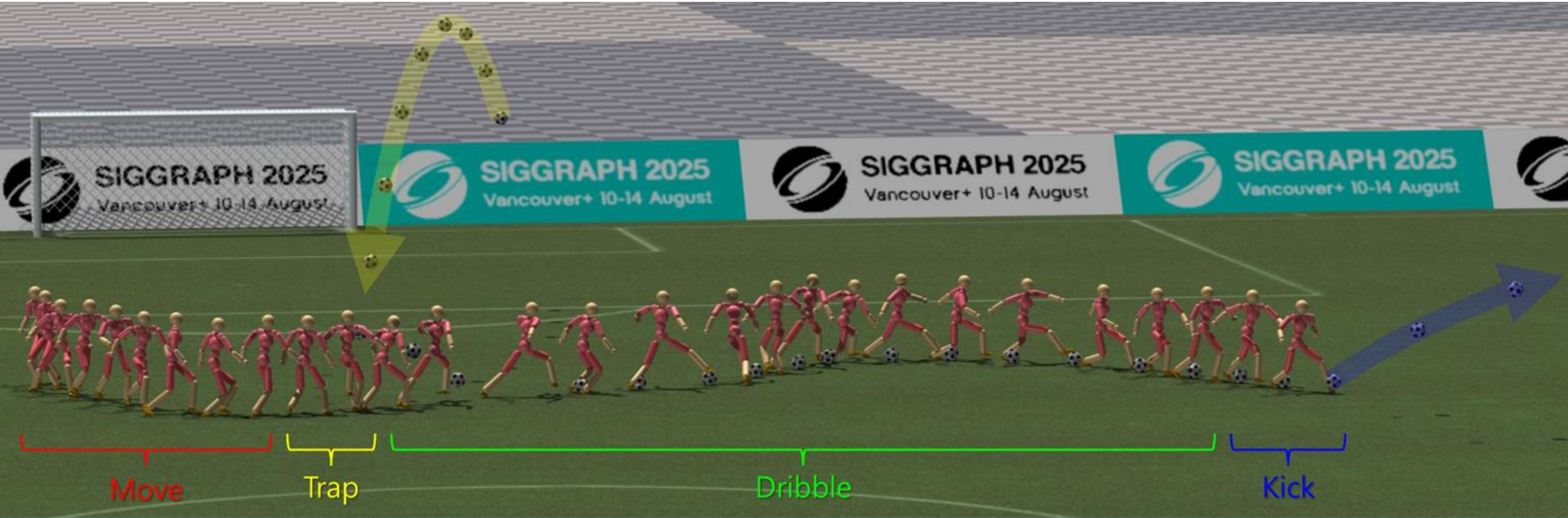
eFootball (Winning Eleven)

- Current football games : kinematic character + physics-based ball

→ Unrealistic character movement!

PHYSICS FC

- We propose **PhysicsFC**, a method for **controlling physically simulated football player characters**.
- Variety of football skills–such as **dribbling, trapping, moving, and kicking– based on user input**.
- **Seamless transition** between these skills.

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CHALLENGES

- The character must **follow user commands** & **interact with the ball.**
  → Use a **hierarchical control structure.**

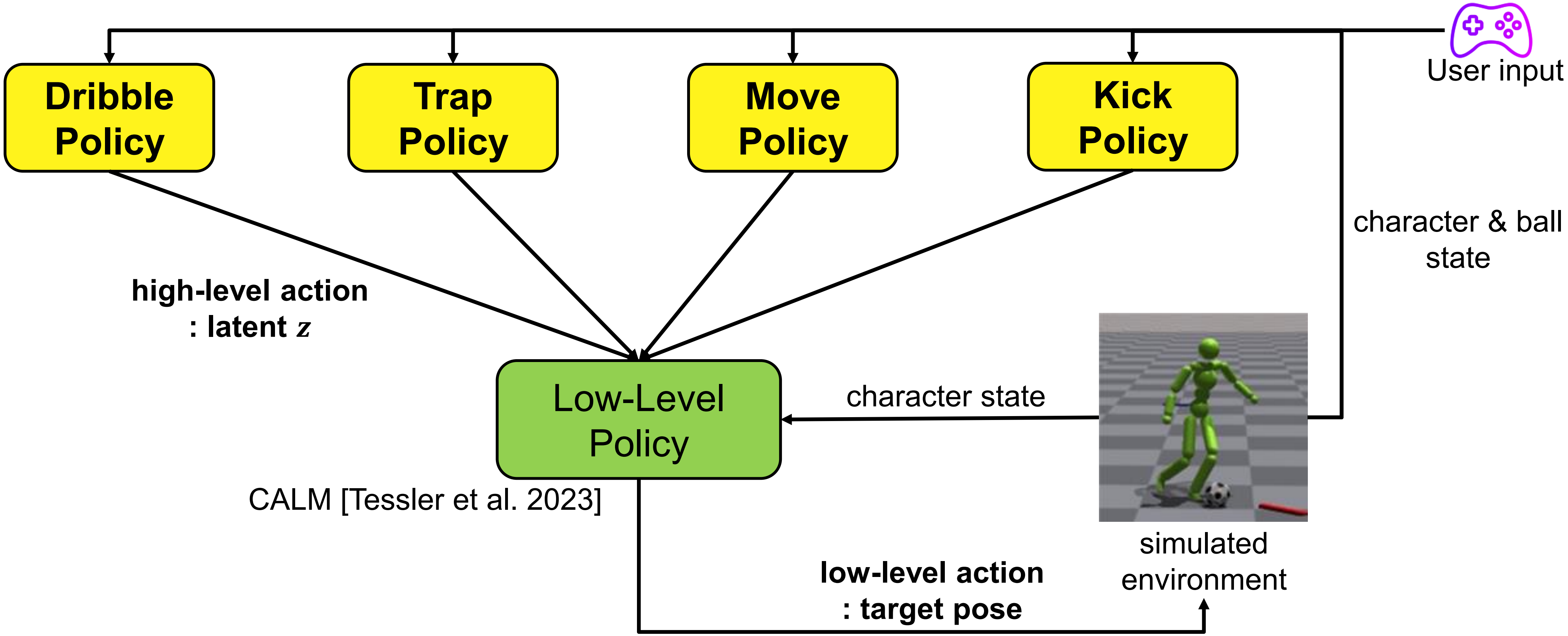
- The character must perform **various skills**.
  → **Each skill policies** learned with **tailored rewards, initialization, and training.**

- The character must **transition** between skills **smoothly and quickly**.
  → Proposed the **Skill Transition-Based Initialization (STI).**

- Each skill and transition must be **user-controllable** and **context-responsive**.
  → Proposed the football player finite state machine **(PhysicsFC FSM).**

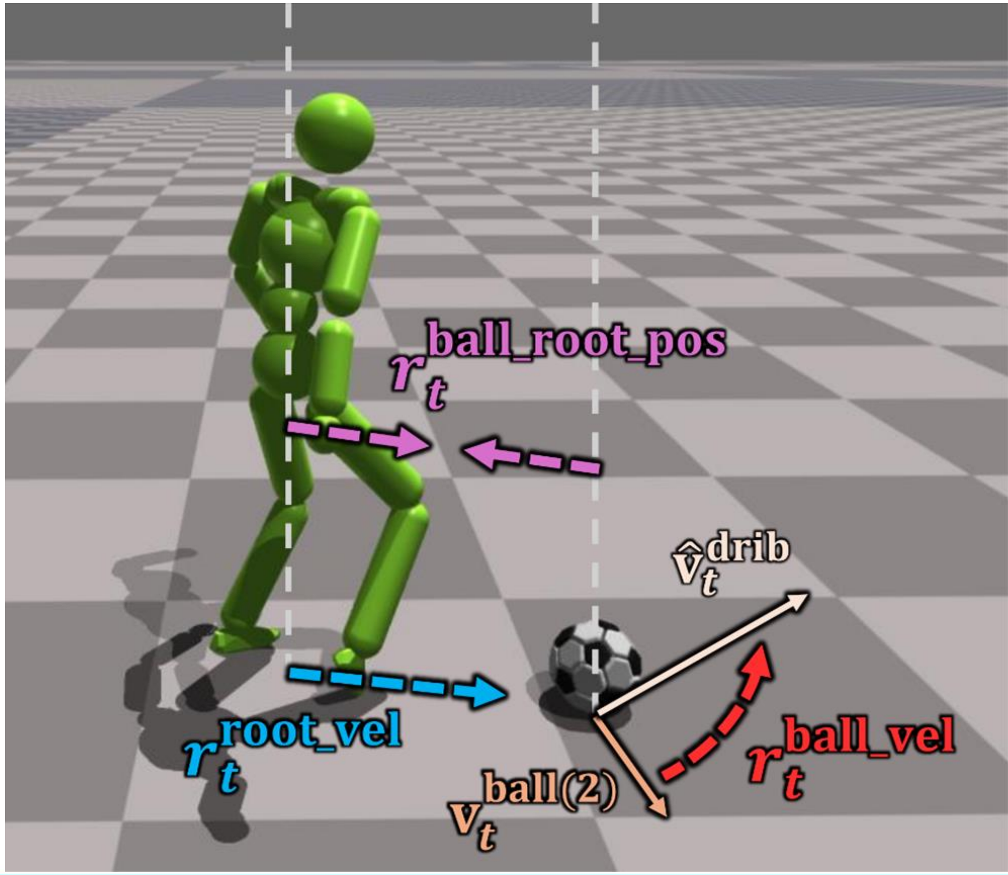
OVERVIEW

Each skill = separate policy (trained individually)



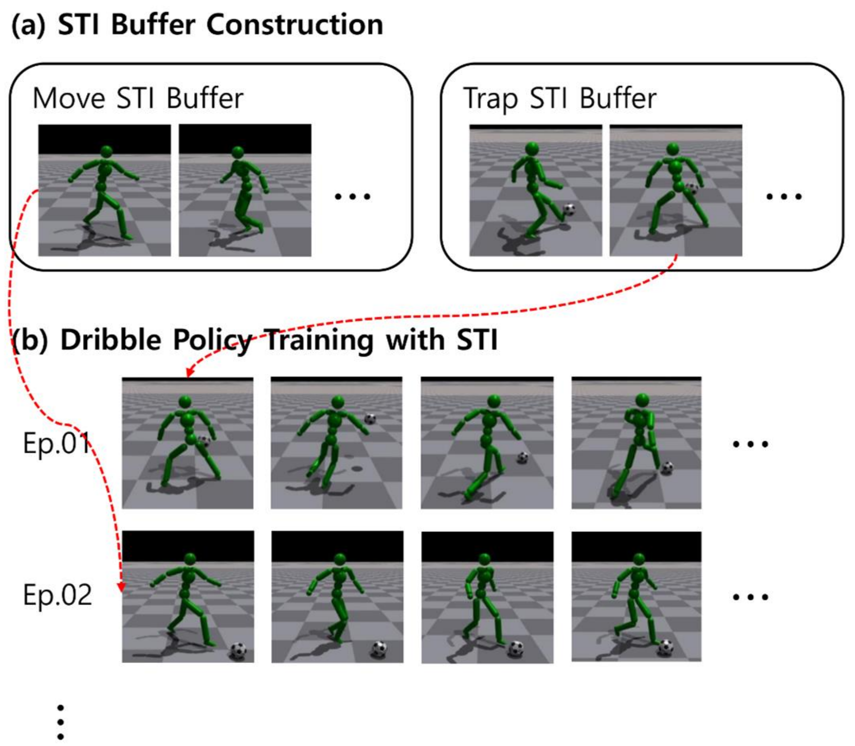
DRIBBLE POLICY

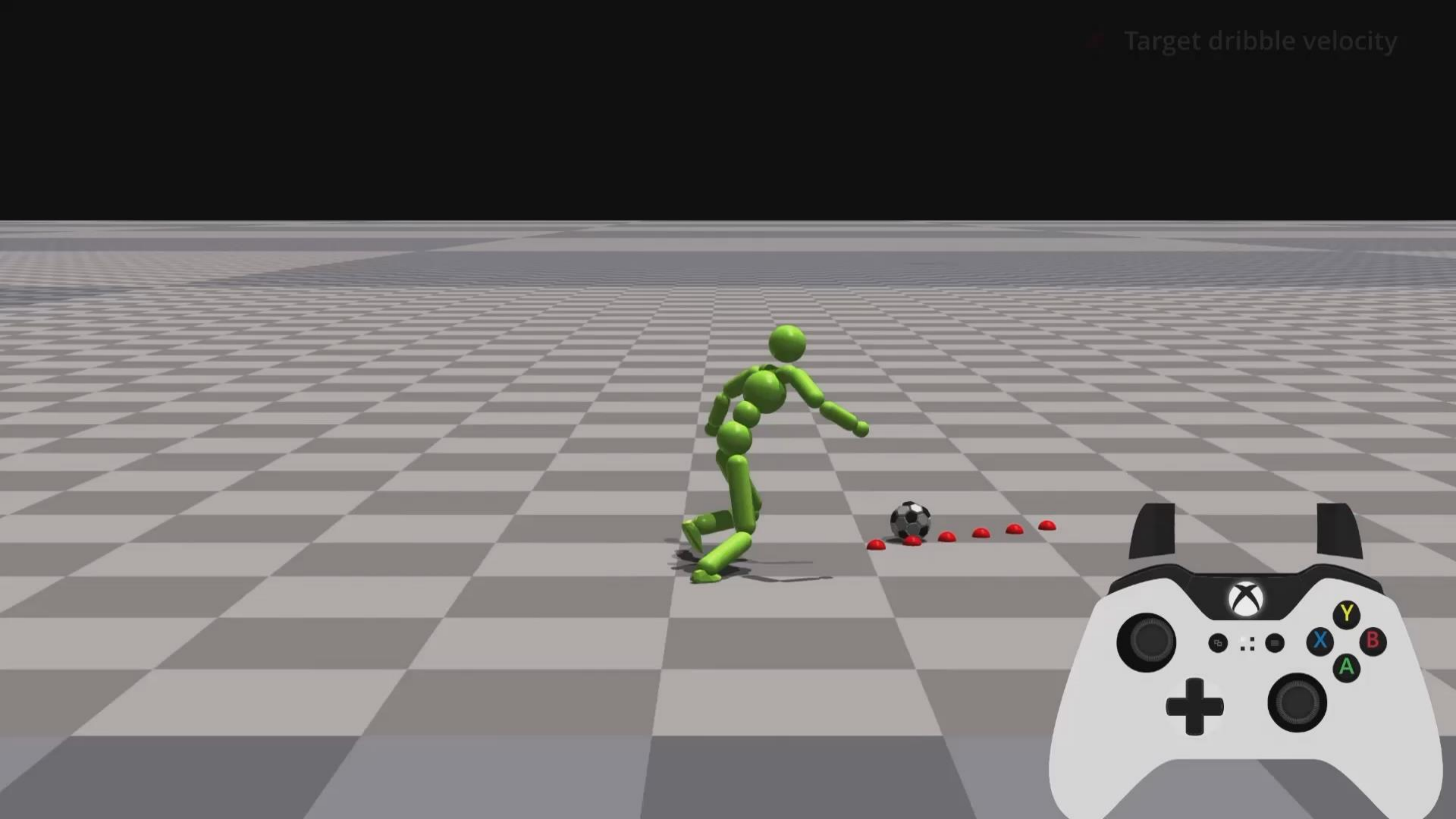
- **Goal** : Dribble at target speed while keeping ball close
- **Input** : Target dribble velocity
- **Reward** : $r_t^{\text{drib}} = 0.6\, \underline{r_t^{\text{ball\_vel}}} + 0.2\, \underline{r_t^{\text{ball\_root\_pos}}} + 0.2\, \underline{r_t^{\text{root\_vel}}}$
  - **ball_vel → target velocity**
  - **ball ↔ foot (stay close)**
  - **root → ball @ target speed**



STI: SKILL TRANSITION-BASED INITIALIZATION

- **Quick and smooth skill transitions are crucial in a football.**
- **Problem**: Separately trained skills → transitions are not agile and natural
- **Solution**: **STI** that initialize new episodes from previous skills
- **Method**: Sample from **STI buffer** during training



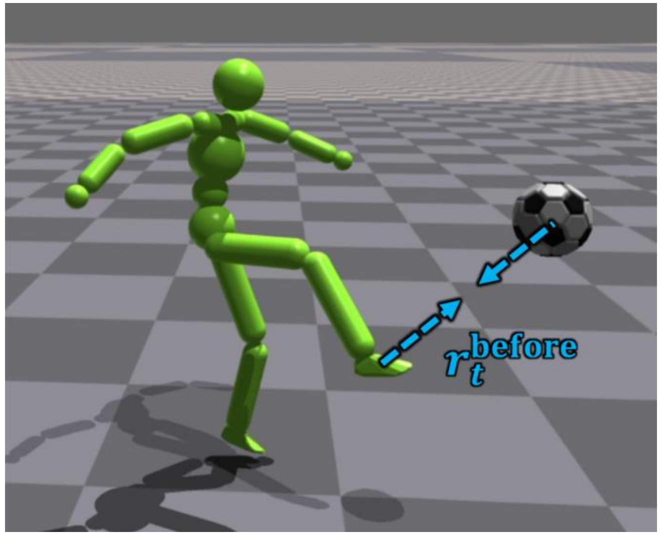

Target dribble velocity
Y
X
B
A

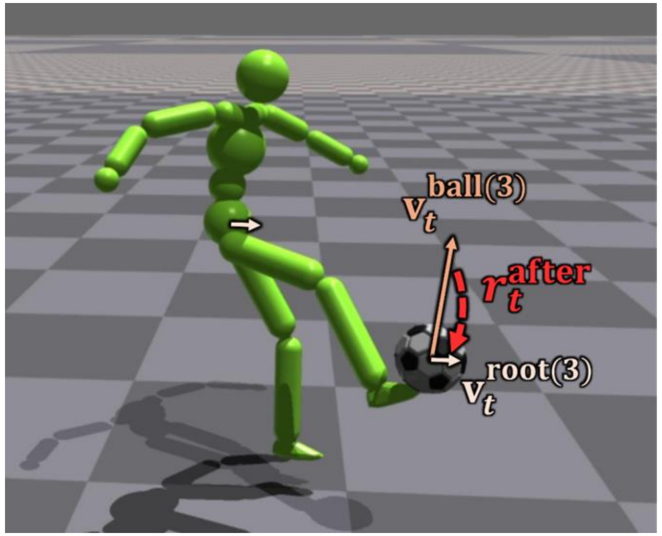
TRAP POLICY

- **Goal** : Trap the ball with a specified body part
- **Input** : One-hot vector (target body part)
- **Reward** :

$$r_t^{\text{trap}} = \begin{cases} r_t^{\text{before}} = \exp\left(-10 \left\| \mathbf{x}_t^{\text{ball}(3)} - \mathbf{x}_t^{\text{body}} \right\|^2\right), & \text{if } t \le t_c \\ r_t^{\text{after}} = \exp\left(-10 \left\| \mathbf{v}_t^{\text{ball}(3)} - \mathbf{v}_t^{\text{root}(3)} \right\|^2\right), & \text{otherwise} \end{cases}$$

  - **Before** : body → ball (minimize distance)
  - **After** : v_ball ≈ v_root (smooth stop)

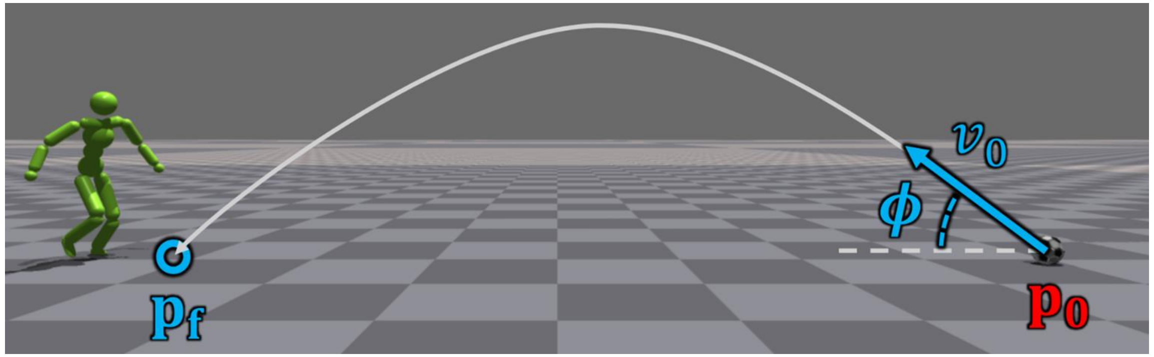




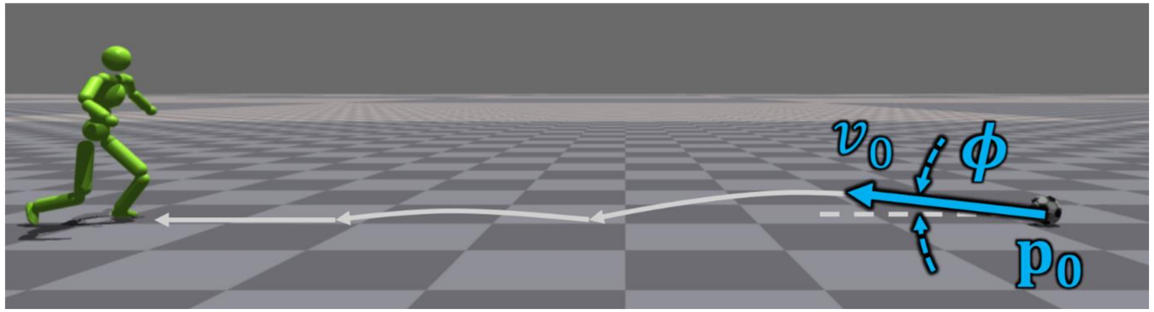
TRAP POLICY: EPISODE INITIALIZATION

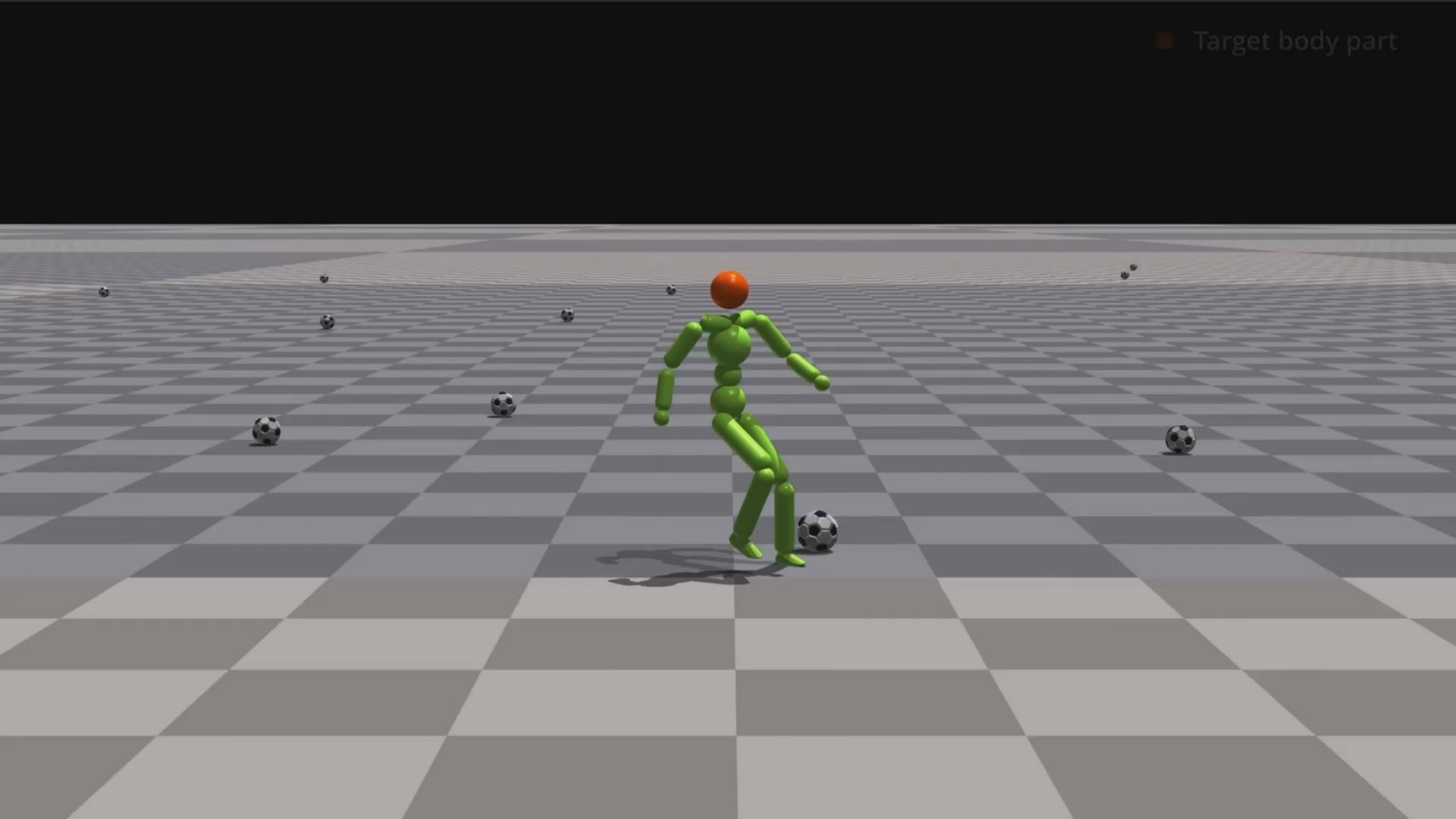
- In trap policy training, proper **episode initialization** is important

- **Ball (lob):**
  - Random: launch angle, speed, landing position
  - Computed: initial position ← **from projectile dynamics**



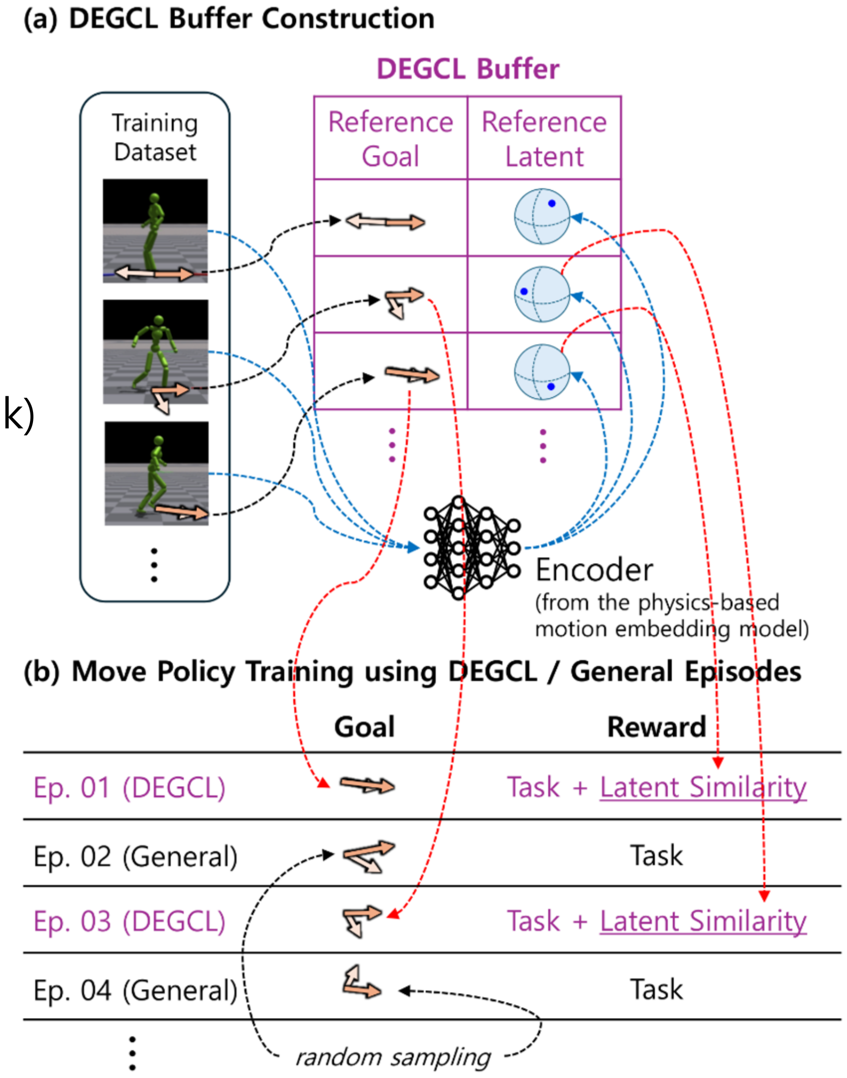
- **Ball (ground):**
  - All params (angle, speed, landing, initial) sampled randomly



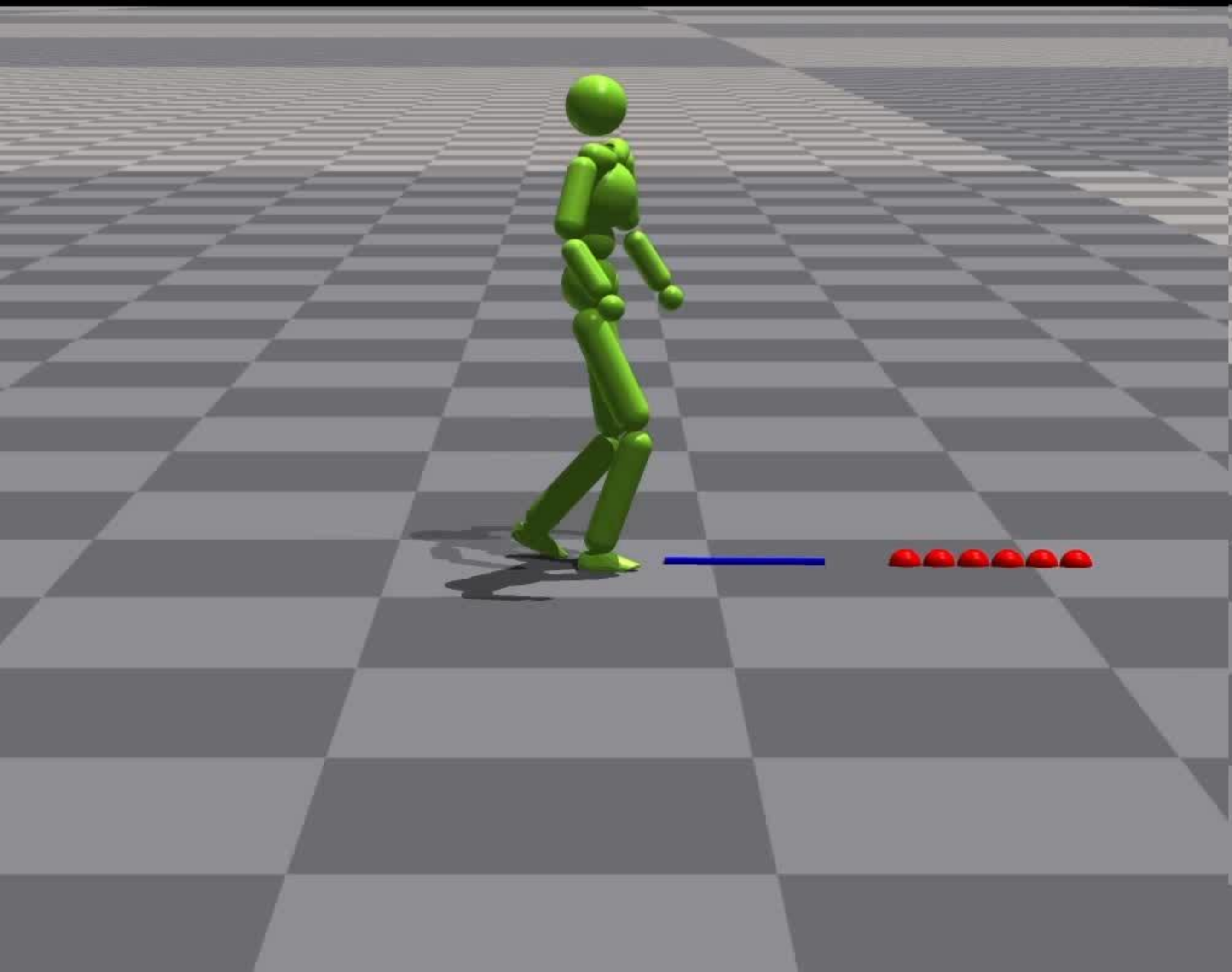

Target body part

MOVE POLICY: DEGCL TRAINING

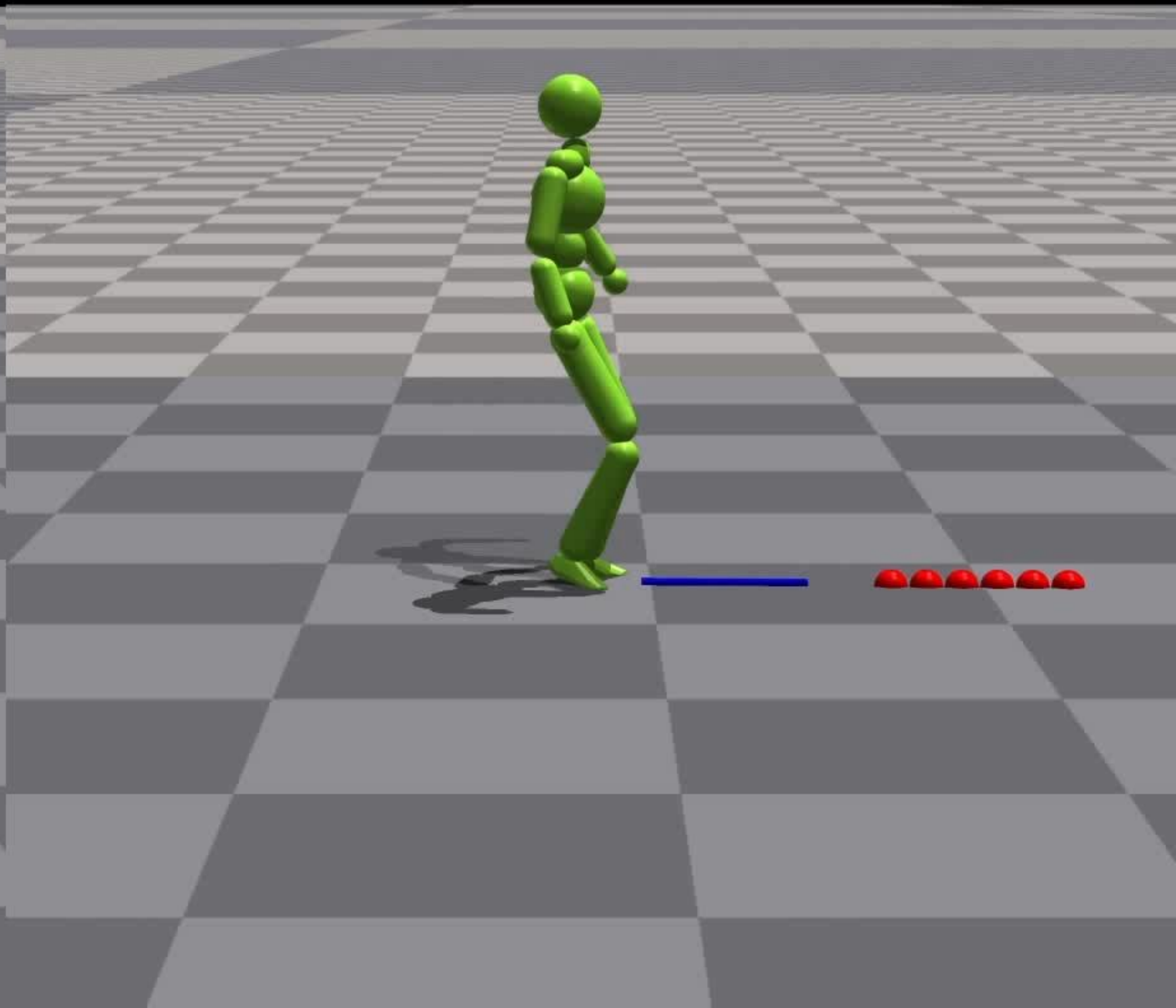
- **Goal** : Control move velocity, facing direction
- **DEGCL** : Data Embedded Goal-Conditioned Latent Guidance
  → Guides the policy using motion data's latent goal-action relationship
- **Why?**
  - Task-only training may miss diverse motions (e.g., sideways/backward walk)
- **How?**
  - **Sample (Reference Goal, Reference Latent)** from motion dataset
  - Train policy to align latent z output with reference latent z
  - Reward: task + latent similarity (only in DEGCL episodes)



Ours



w/o DEGCL



KICK POLICY

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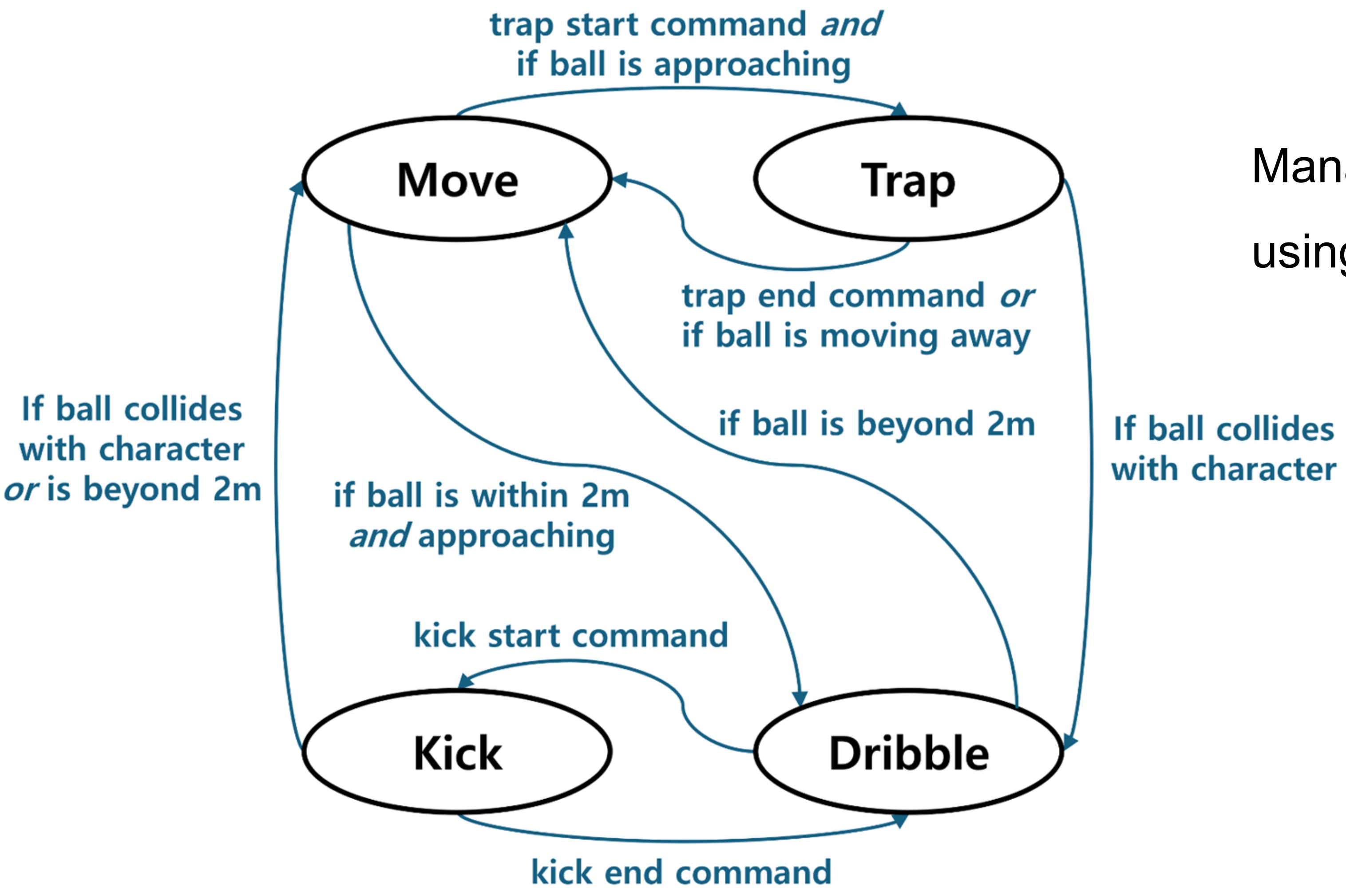
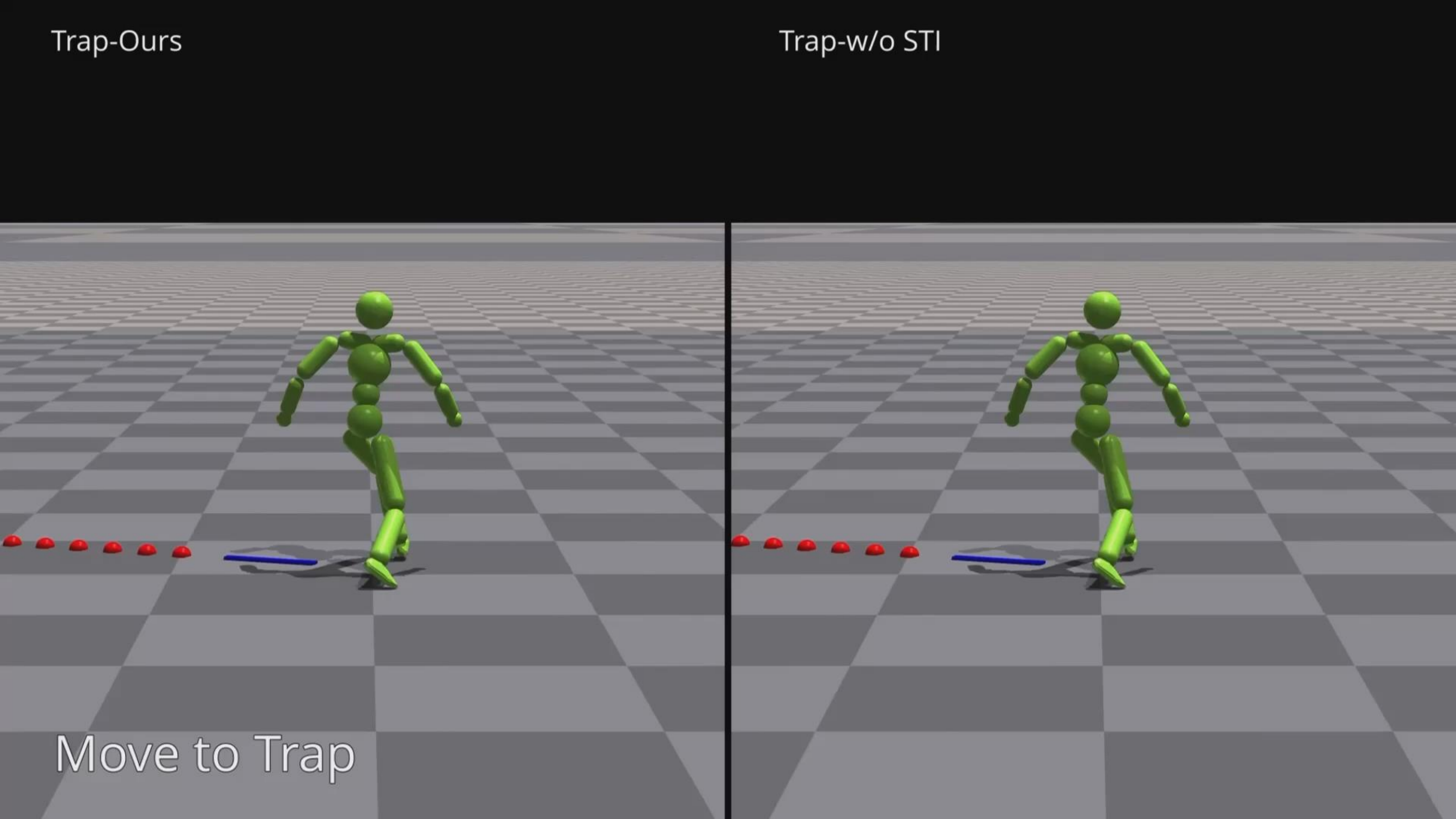
- **Goal** : Kick with target velocity
- **Input** : Target kick velocity (3D)
- **Reward** : $r_t^{\text{kick}} = \exp\left(-\left(\frac{\left\|\hat{\mathbf{v}}_t^{\text{kick}} - \mathbf{v}_t^{\text{ball}(3)}\right\|}{\|\hat{\mathbf{v}}_t^{\text{kick}}\| + \epsilon}\right)^2\right)$
  - **ball_vel ≈ target velocity (direction + speed)**
  - evaluated briefly after contact

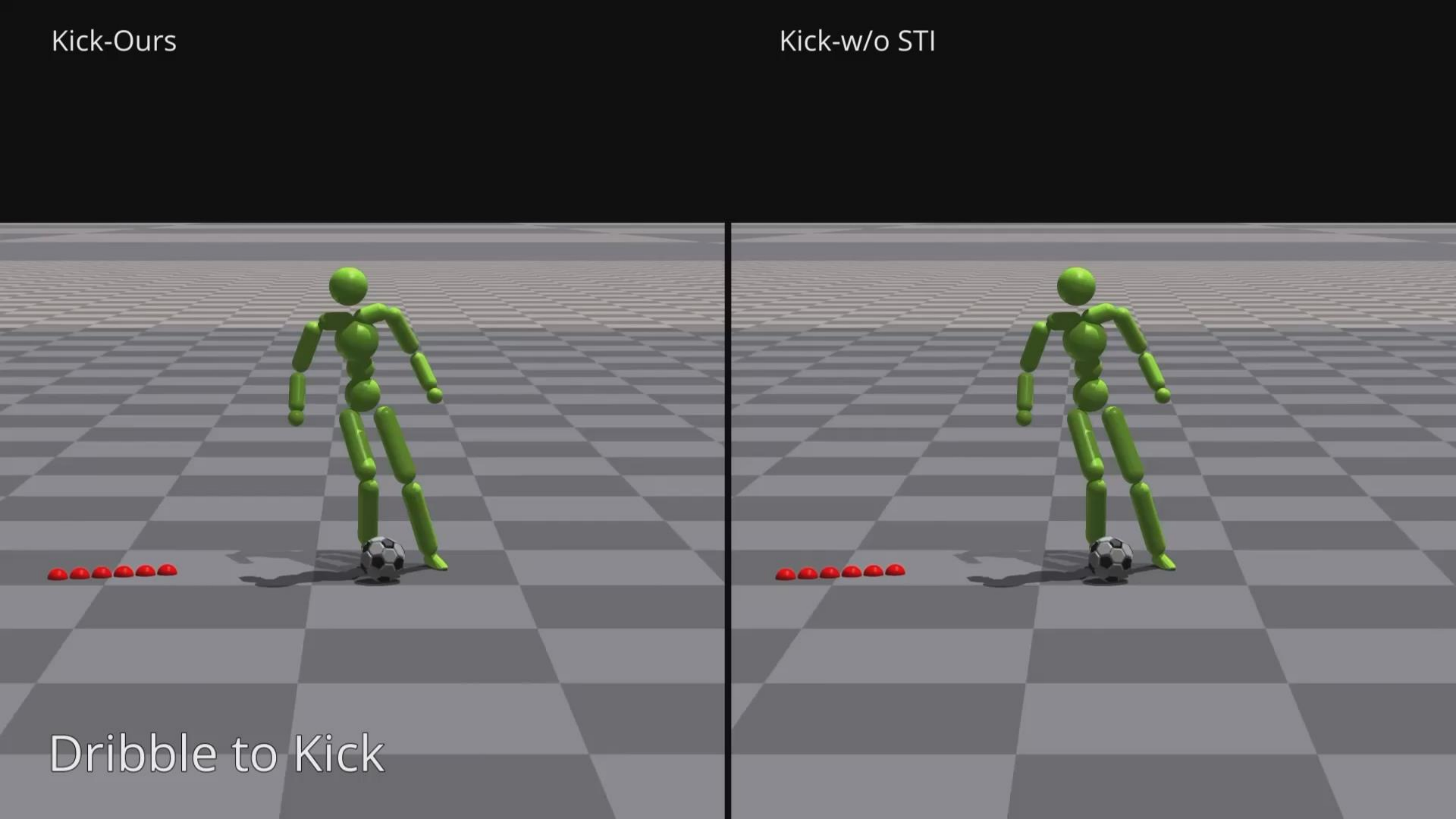

Expected ball trajectory

PHYSICSFC FSM



Manages transitions between learned skills using predefined rules.


Trap-Ours
Trap-w/o STI
Move to Trap


Kick-Ours
Kick-w/o STI
Dribble to Kick

QUANTITATIVE EVALUATION

- **Defined dedicated performance metrics** for each **individual skill** (Trap, Dribble, Move, Kick) and for **skill transitions** (e.g., Dribble→Kick).
  - Example: **Trap** skill - **Trapping Success Rate (TSR), Handball Ratio in Trapping Success (HRTS)**, **Relative Ball Speed Post-Trap (RBSPT)**

	TSR(%)↑	HRTS(%)↓	RBSPT(m/s)↓
Trap-w/o r_t^{before}	28.6	**5.1**	4.75
Trap-w/o r_t^{after}	74.2	9.3	4.43
Trap-w/o ProjectileInit	21.1	5.2	5.22
Trap-w/o HandArmET	77.1	20.7	3.94
Trap-Ours	**78.3**	5.6	**3.69**

Trap skill evaluation

	KSR(%)↑	TTK(s)↓	KDD(°)↓	KSD(m/s)↓
Kick-Ours	**100**	**2.99**	**16.9**	**5.81**
Kick-w/o STI	16.95	3.35	37.41	7.21

Dribble→Kick evaluation

→ **Comprehensive evaluation of both skills and transitions validates our approach**

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Come to our table to play the game!