Cat-Righting Reflex Animated with a DRL Approach

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CMPT 766 Computer Animation

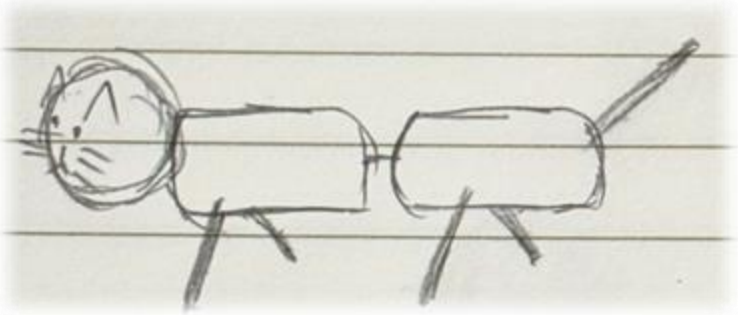
November 27, 2025

The Cat-Righting Reflex

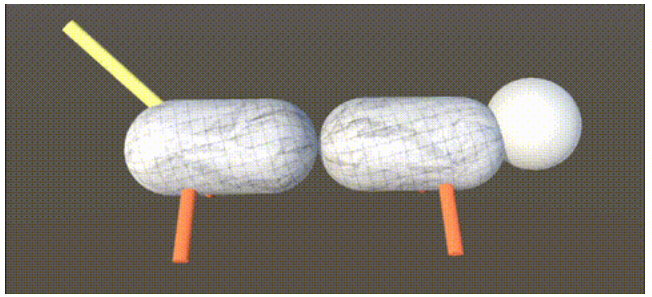
- Cats can rotate mid-air to land on feet
- No external forces to push against
- Angular momentum = 0 throughout

Physical Model

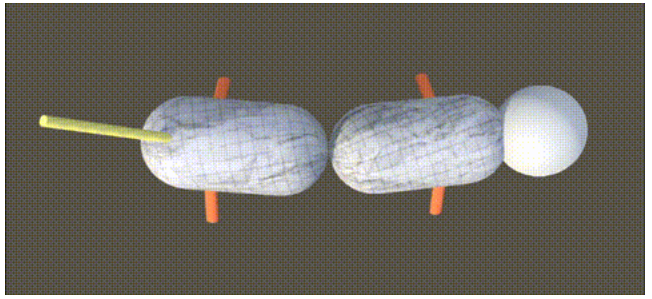
- “Flexible Spine”
- Two Rigid Bodies
  - FrontBody
  - BackBody
- One Spherical Joint
  - 3 DoF



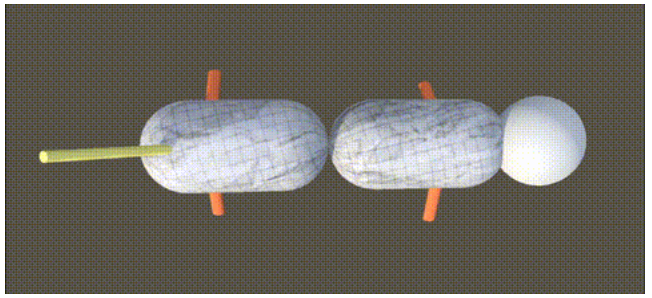
“Le manuscrit original”



DoF 1: Spine Bending (0° – 100°)

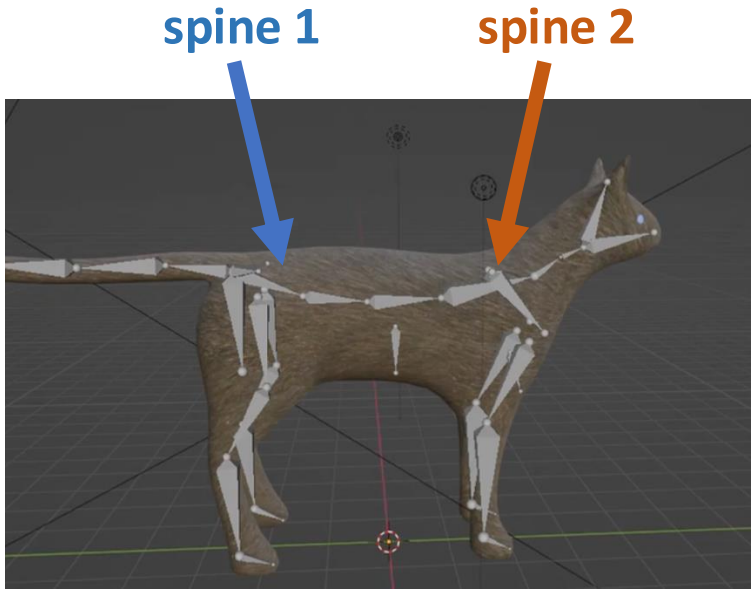


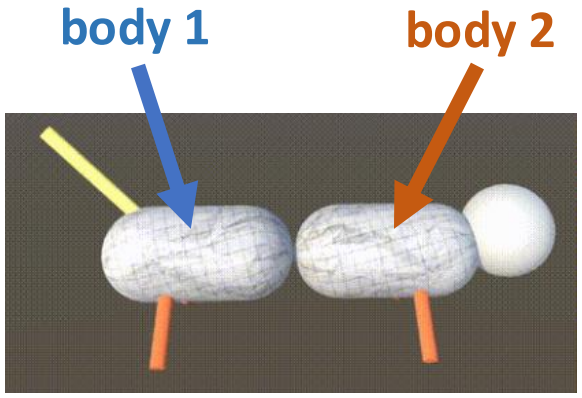
DoF 2: Lateral Bending (±50°)



DoF 3: Twisting (±120°)

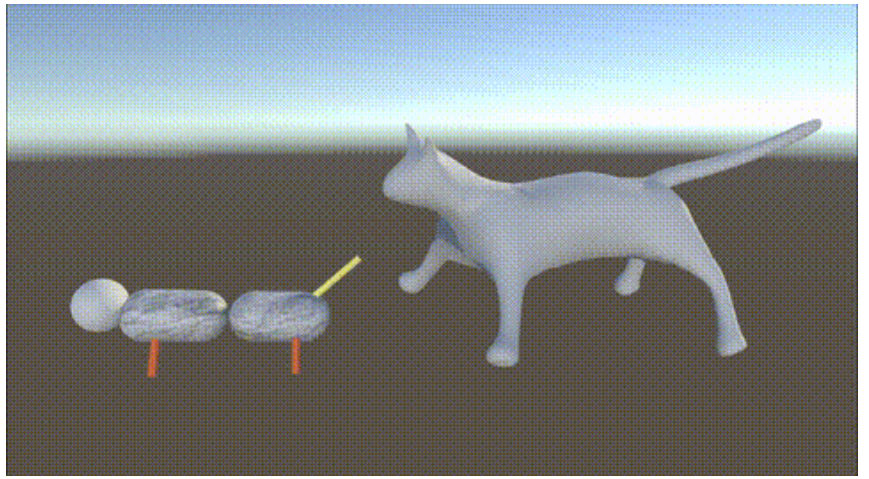
Physics to Visual





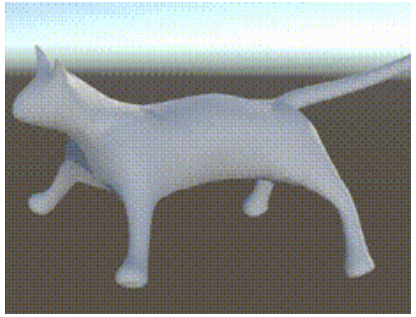
- Skeletal Rigging
  - Rigged cat model with bones
  - Skins deform with bones

- **Two spines** follow the **rotation** of the **two bodies**, respectively



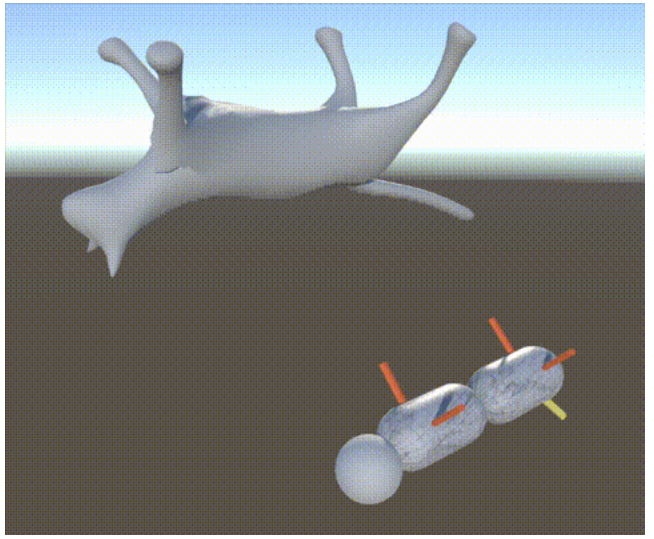
Physics of mid-air flipping

- Wiggling only leaves you in place ☹
- **Physics actually allows it!**
  - Angular momentum conservation
  - Cats already know!



No net rotation at all!

- Control it manually?
  - Yea, but clumsy
- Can DRL learn something better?
  - Definitely!

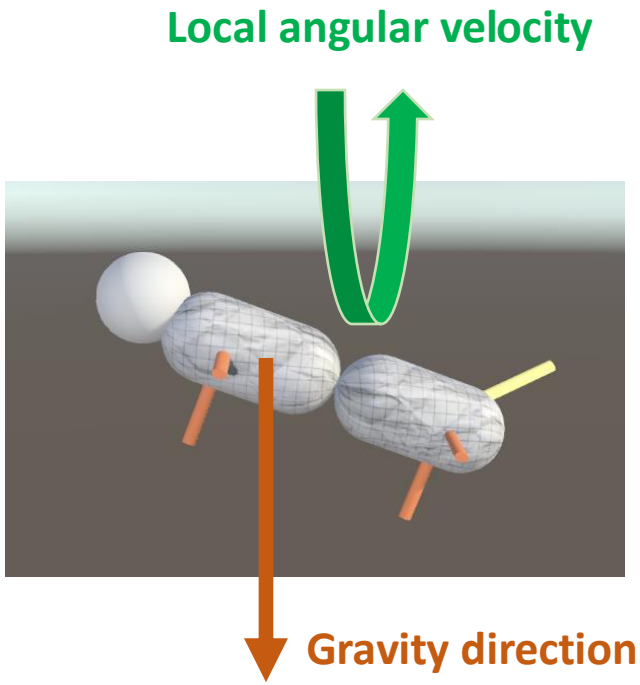


Manually controlled by me
(clumsy, 3x speed)

Learning self-driven: DRL

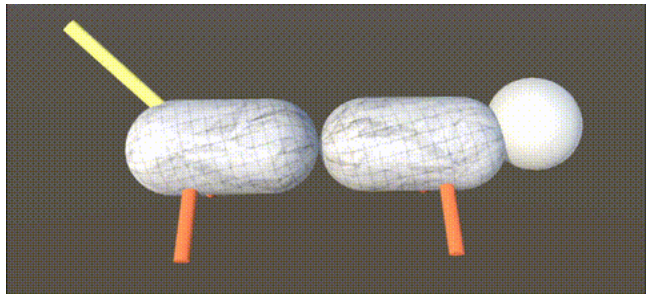
- **Observations** – what the cat can see/feel
  1. **Gravity direction** (Which way is down?)
  2. **Local angular velocity** (How fast am I rotating?)

  → Mimics real cats' self-awareness



- **Policy** – cat's brain
  - Simple MLP (2 layers, 32 hidden units each)
  - Learn with PPO Algorithm

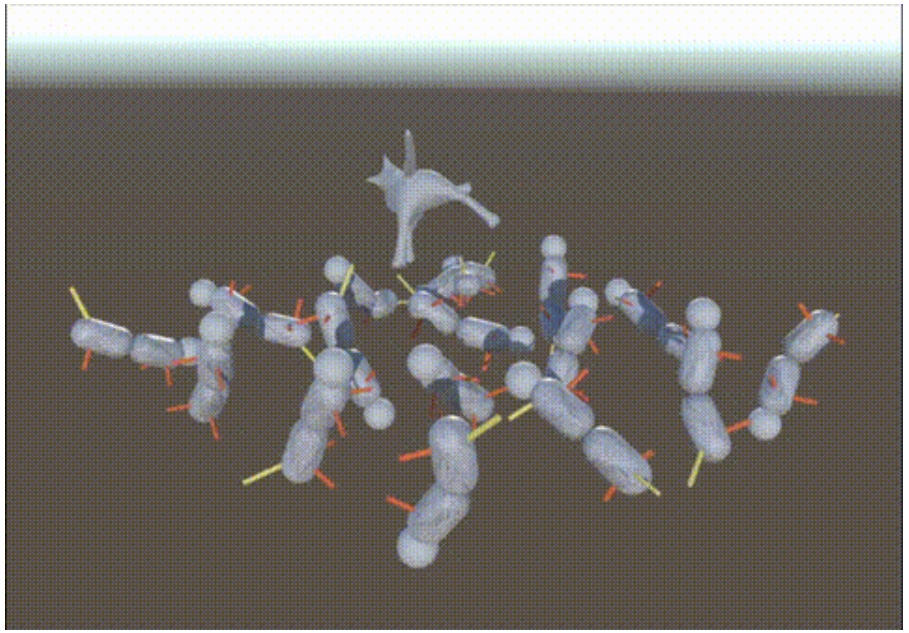
- **Action** – what the cat can do
  - **Angular velocity** for each DoF of the joint



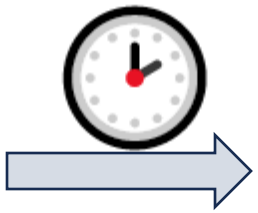
Action [90, 0, 0] rotates the first DoF by 90°/s

Training Process

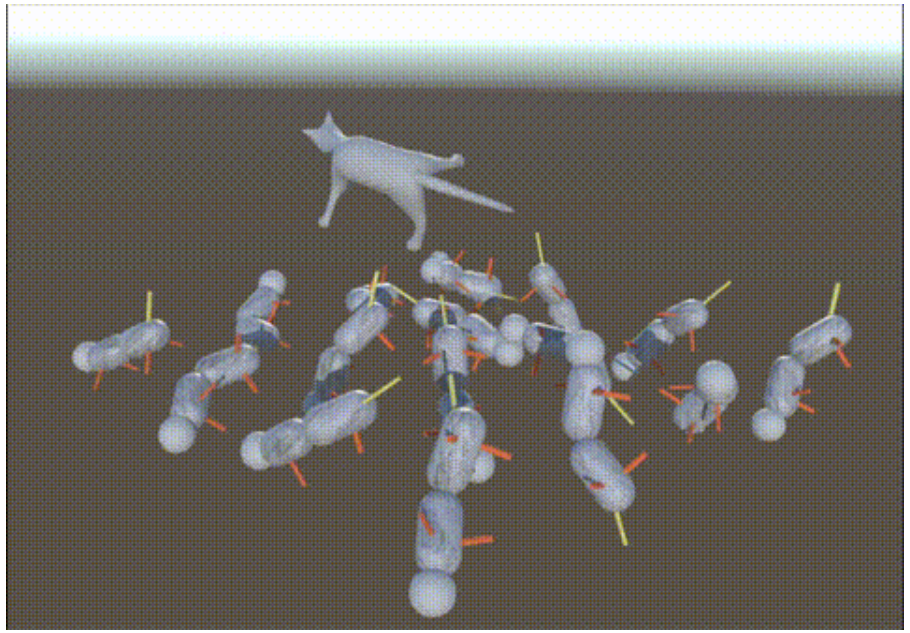
- Random initial orientation each episode (3s per episode)
- 16 parallel environments
- Early Training



struggle to adjust posture ☹



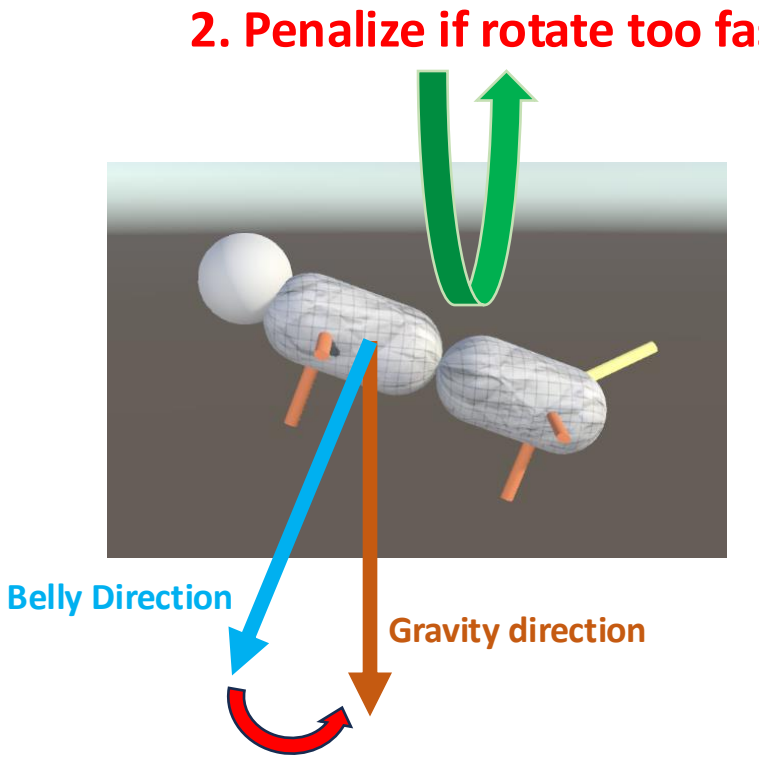
- After Convergence

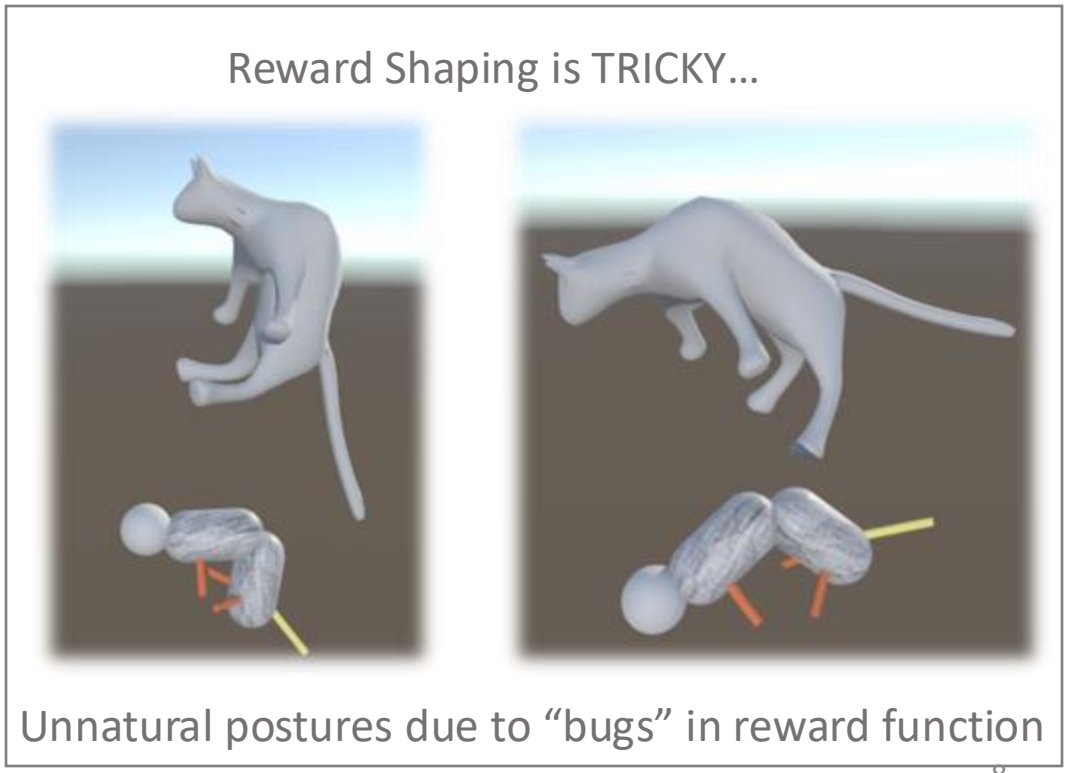


turn belly-down quickly ☺

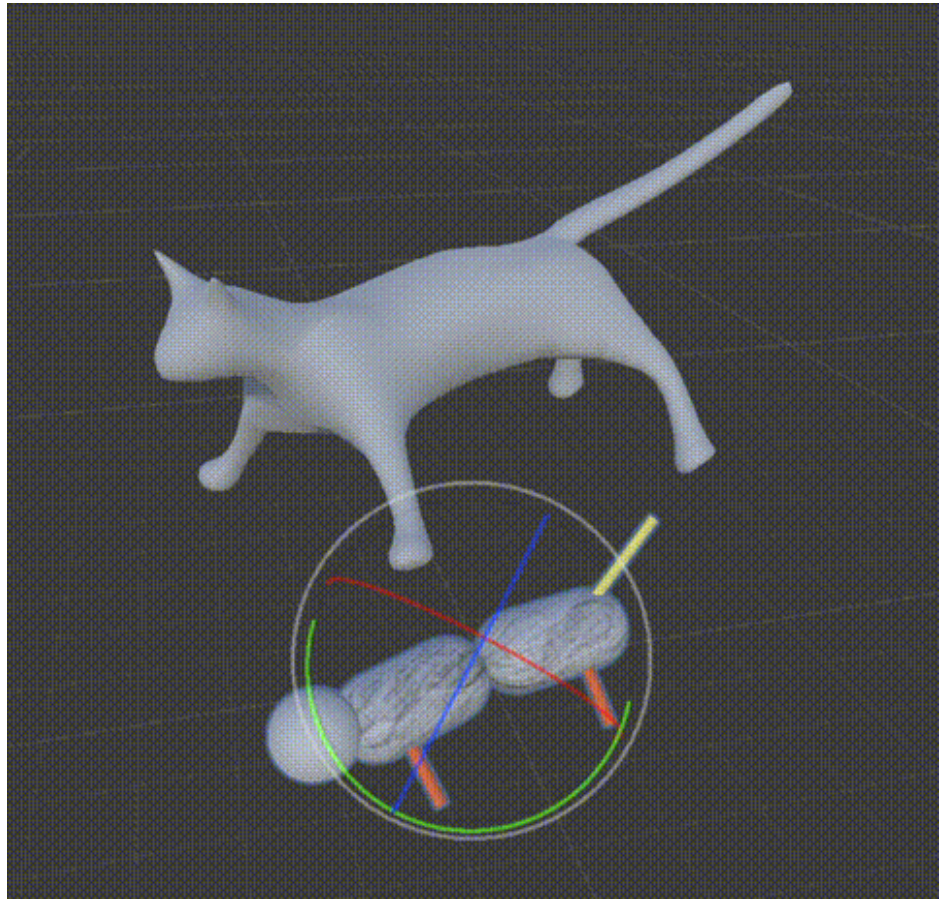
Reward Shaping

1. Belly-Direction Penalty
2. “Save Energy” (prevent unnecessary shaking)

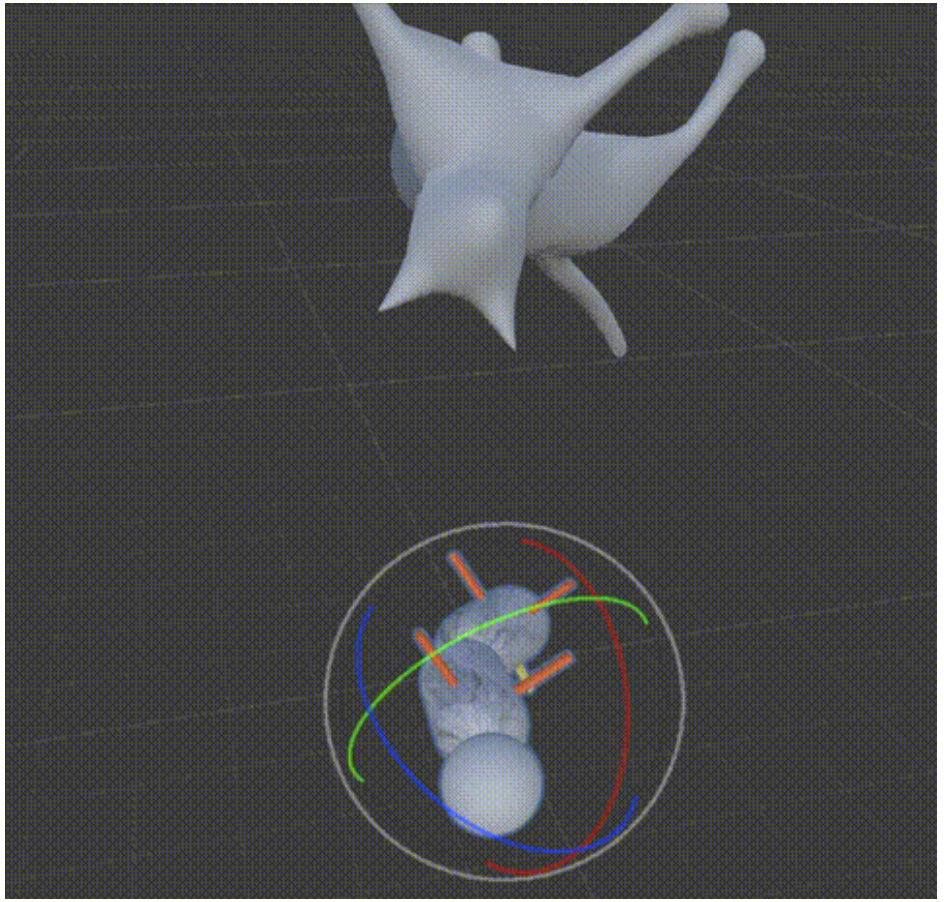




Converged Result



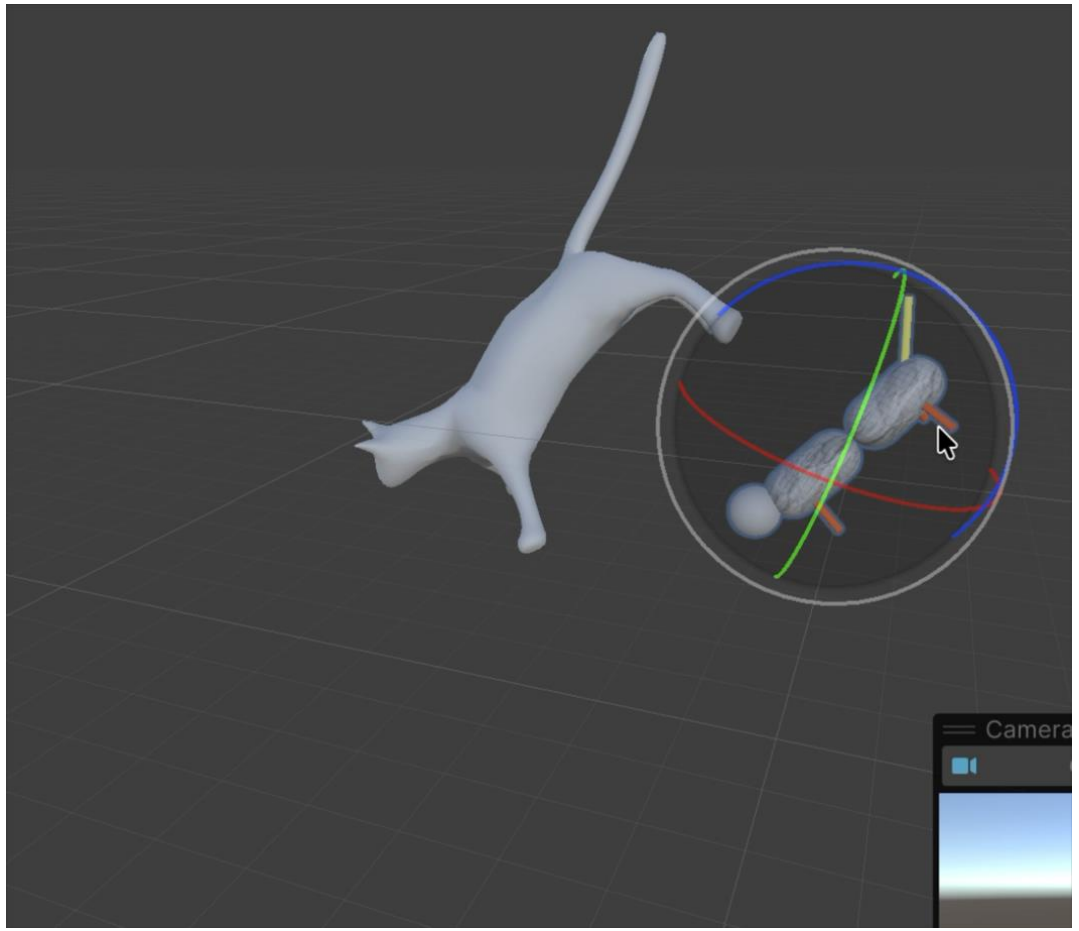
Normal Speed



Slow Motion (0.1x)

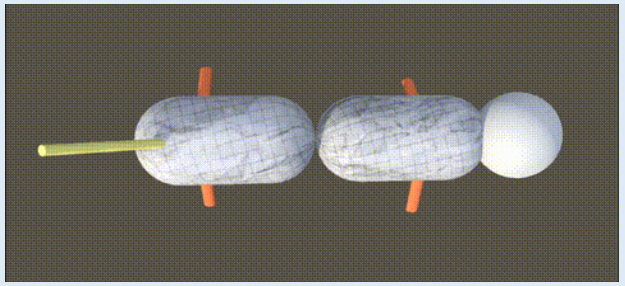
Live Demo in Unity

1. RL Agent Auto-Flipping
2. Real-Time Disturbance Test

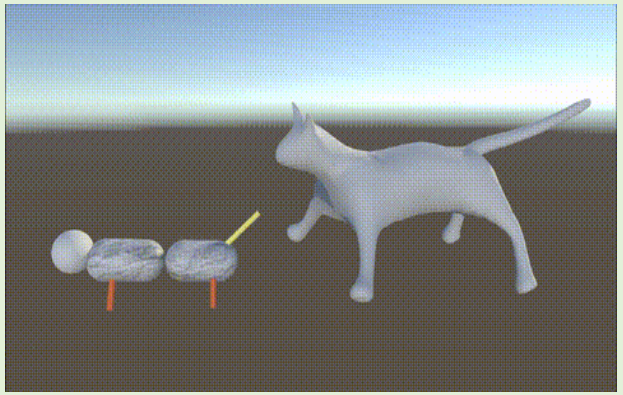


Summary of Core Contributions

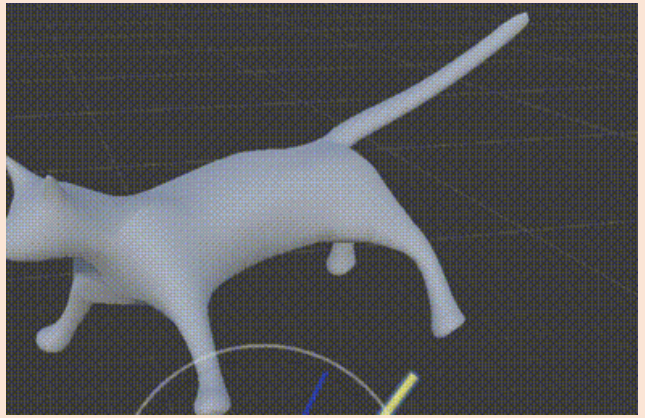
1. **Physics-Based Simulation**
   Rigid body dynamics



2. Physics to Visual
Skeletal rigging system



3. Physics Powered by DRL
Learning physically plausible controls



Application Value - Beyond Motion Capture

- Dangerous / Animal motions hard to capture
- Real-time responsive & adaptive animation
- Extensible to even imaginary creatures!