Learning Decentralized Multi-Biped Control for Payload Transport

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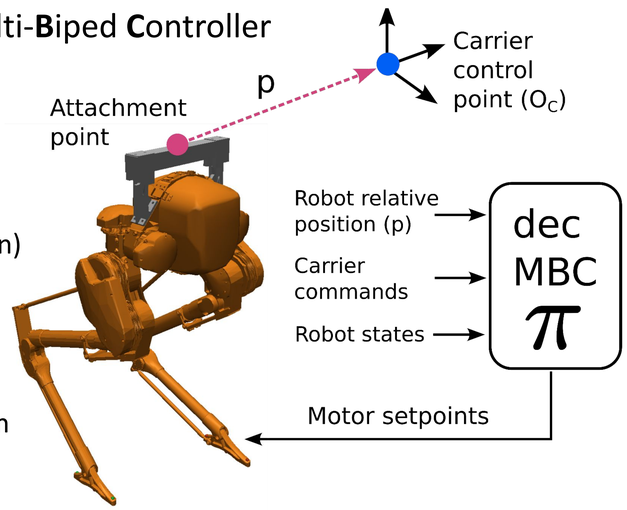
Why Replace Wheeled Carriers?

We propose,
decMBC: **dec**entralized **M**ulti-**B**iped **C**ontroller

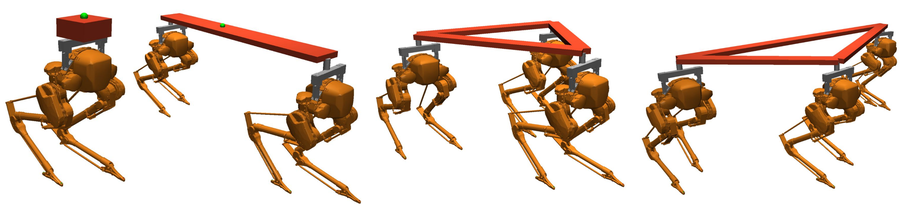
- **First Scalable Multi-biped Transport System**
- **Fully Decentralized Controller** (No inter-robot communication)
- **Reconfigurable** to any carrier shape and number of robots
- **Superior to Wheeled robots** on Rough terrain



How Did We Train decMBC?

- **Reinforcement learning** used to train robots with up to 3 in the Mujoco Simulator.
- We applied **Independent Proximal Policy Optimization (IPPO)** to train the shared decMBC controller (50Hz) using data from multiple robots without any communication between them.
- **Neural network architecture:** 2 LSTM layers with 64 hidden units.
  - **Input:** Local robot state and carrier control point.
  - **Output:** 10-dimensional motor set points for a 2kHz PD controller.
- Training stages:-
  - **Stage 1:** Teach 1 robot stable walking with carrier commands.
  - **Stage 2:** Add disturbances (e.g., torsion) to improve robustness.
  - **Stage 3:** Train 2-3 robots, randomizing carrier points.
  - **Stage 4:** Simulate real-world conditions with payload variations and forces.

★ **Simulation Training:** Upto 3 robots, parallely

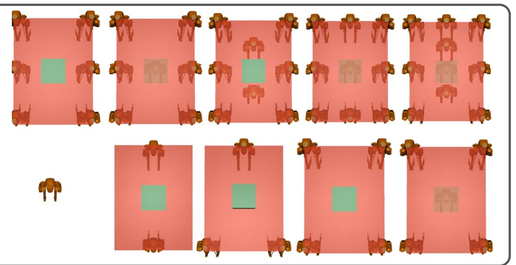


SCAN ME !

Experiments Result and Hardware Deployment

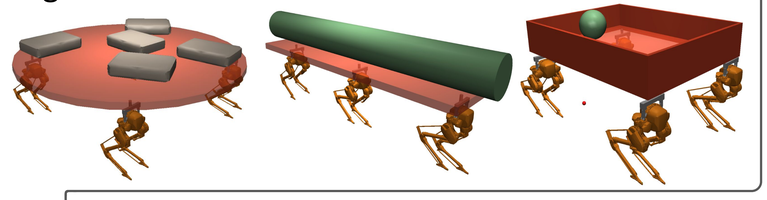
★ **Simulation Testing:** Varying number of Robots

- **Test:** 2 to 10 robots on a rectangular carrier.
- **Result:** Consistent performance across all configurations, proving that decMBC generalizes beyond its initial training of 1-3 robots.



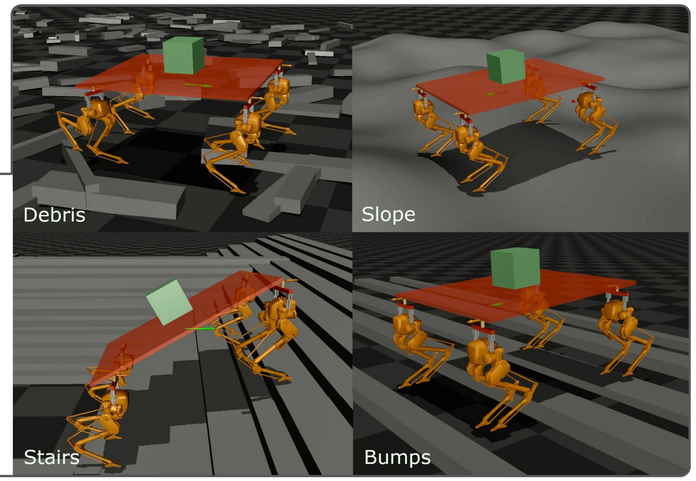
★ **Simulation Testing:** Varying Loads and Configurations

- **Test:** Three real-world carrier setups: a circular carrier with sacks, a long plank simulating a log, and a dynamic container with a rolling ball.
- **Result:** Near-zero drift, except for a 25% error in orientation drift during the dynamic load test due to the unpredictable motion of the rolling ball.



★ **Simulation Testing:** Challenging Terrain (No vision input — Robots are blind!)

- **Test**: Four robot navigating without vision on the challenging terrain with a payload.
- **Result:** Reacts to disturbances, and recover from instabilities, all without any vision input.



★ **Real hardware Testing**

- **Test:** We tested our policy on real Cassie robots (two and three) attached to I-shaped and T-shaped carriers, using a joystick to control the payload-carrying carrier.
- **Result:** The robots successfully maneuvered payloads in real-time, responding to commands and maintaining stability.