FlipWalker: Jacob's Ladder toy-inspired robot for locomotion across diverse, complex terrain

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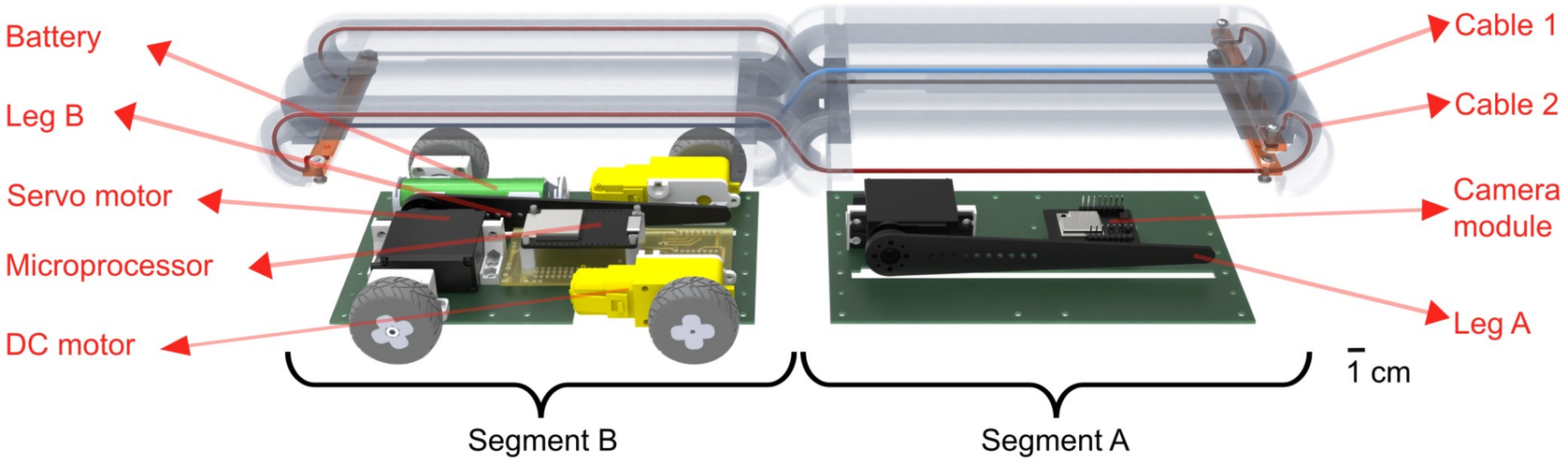
Access to video and more:

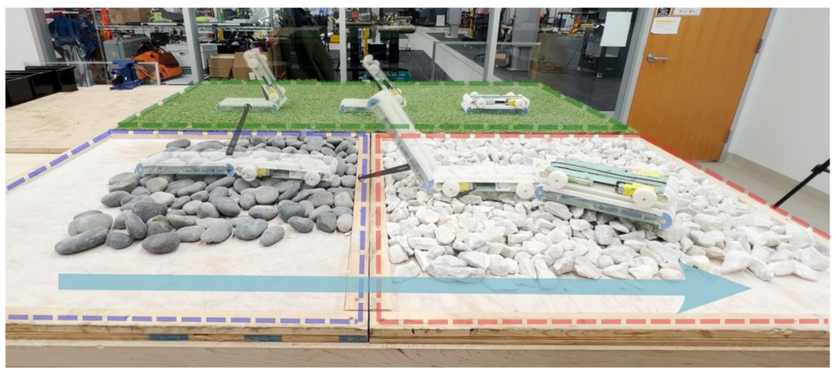
Concept & Design

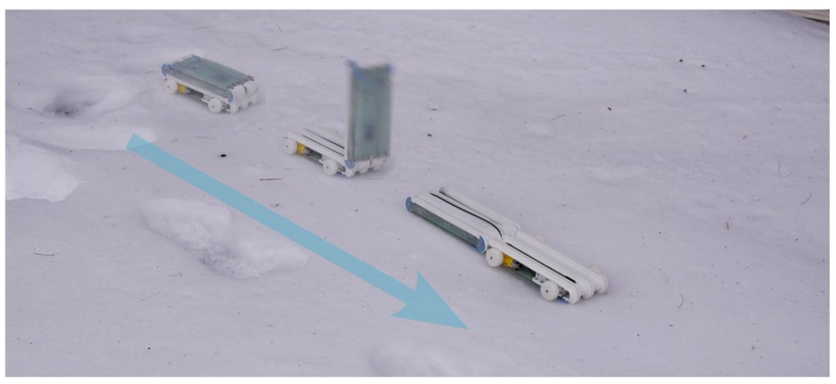


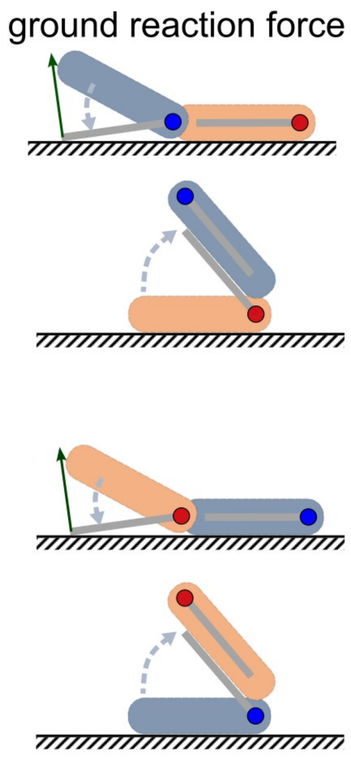
Jacob's ladder of Queen Victoria and Prince Albert, 1840, Toronto Public Library Special Collections.

Motivation

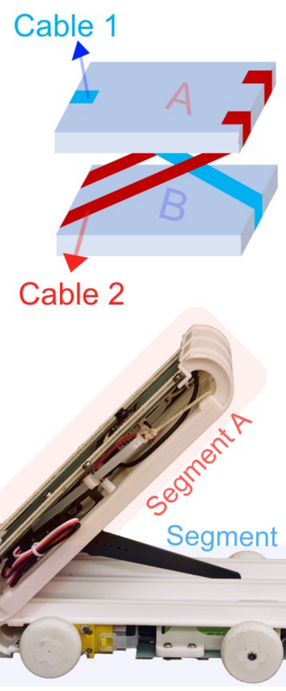
- Traditional (low-profile) wheeled and tracked robots often struggle on irregular outdoor terrain (grass, rocks, snow).
- Applications such as biodiversity monitoring and disaster response demand new locomotion strategies.
- FlipWalker is a novel robot inspired by the Jacob's Ladder toy, achieving locomotion through sequential flipping of body segments.





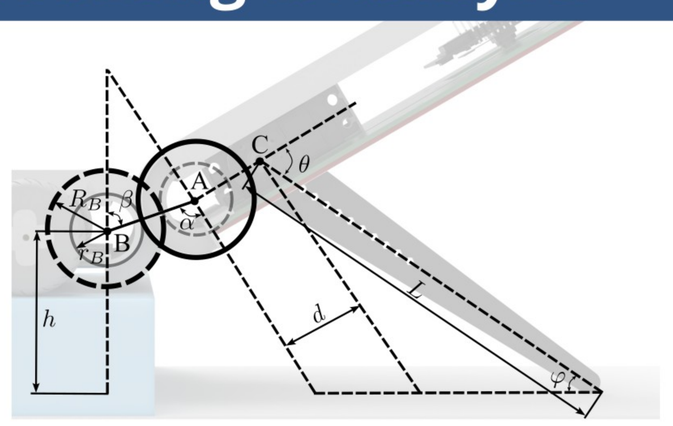


Motor sequence

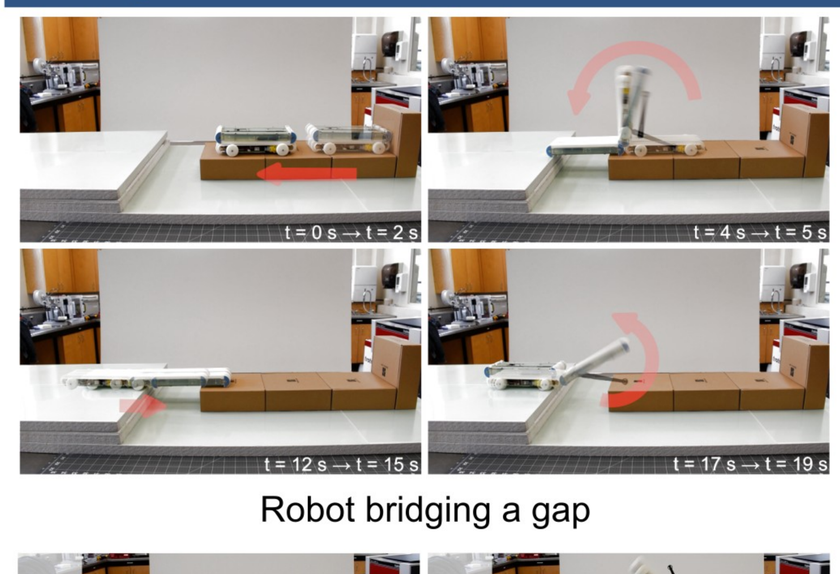


Basic robot configuration

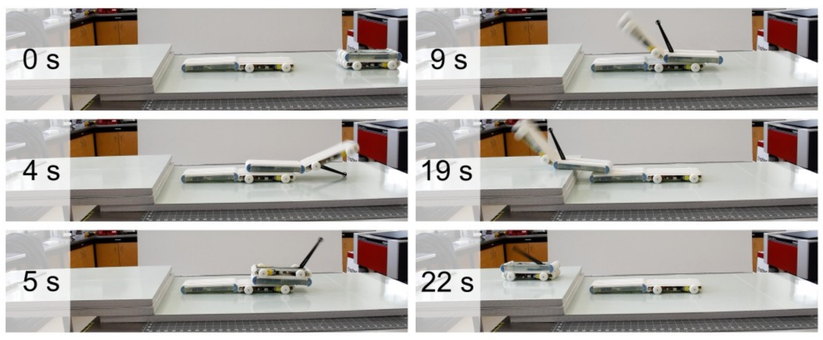
Modeling & Analysis



Experiments



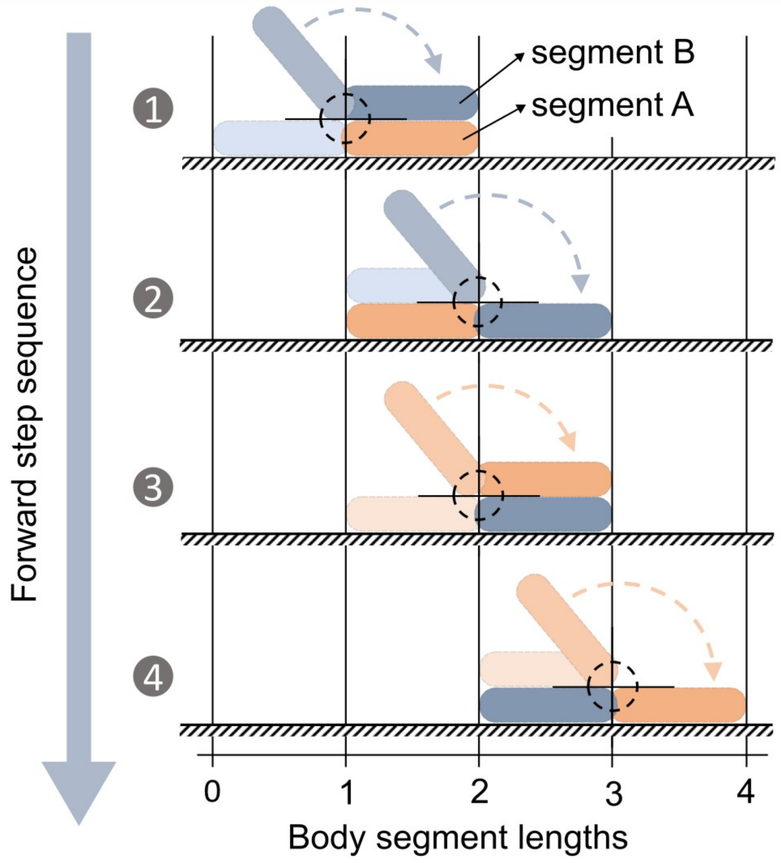
Robot bridging a gap

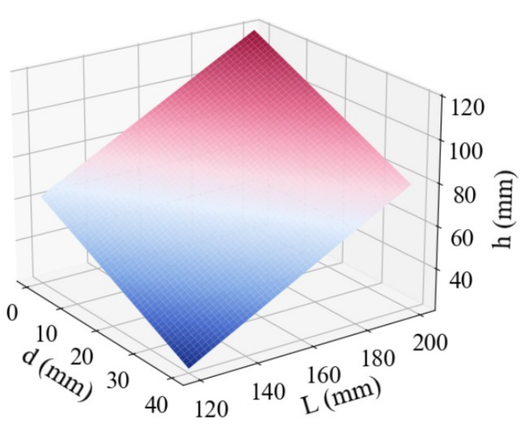


Multi-robot collaboration

- **Terrain Adaptability:** Successful locomotion on grass, river rocks, marble stones, and outdoor snowy ground.
- **Gap Crossing:** Spanned gaps larger than wheelbase using repeated flips.
- **Multi-Robot Collaboration:** Two FlipWalkers cooperatively climbed obstacles up to 138 mm by acting as climber and assistant. (More demos are displayed in the supp video)

Locomotion sequence





- **Geometric Model**: Relates leg length L, motor offset d, and joint angle range θ to climbing height h.
- **Dynamic Model**: Formulated with Lagrangian mechanics; flipping requires sufficient leg torque and ground reaction impulse.
- **Prototype Comparison:**

Short-leg Model S underperforms predictions. Long-leg Model L exceeds predictions due to kinetic energy contribution.

Cost of transport (CoT)

COMPARISON OF ROBOTS: COST OF TRANSPORT (COT) AND WEIGHT

Robots	COT	Weight (kg)
Field robot (> 10 kg)		
ANYmal [40]	1.2	30
Portable field robots (< 10 kg)		
Cheetah-Cub [41]	6.9	1.1
M4 [44]	2.6 – 27.0	5.6
GOAT [42]	0.1 (rolling) / 0.8 (driving)	1.6
ART [43]	10.6 - 30.0	9
Pocket field robot (< 1 kg)		
Flipwalker	16.98 (flipping) / 3.27 (driving)	0.77

FlipWalker introduces **a new locomotion strategy** that combines stability, modularity, and terrain adaptability.

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