THE COST OF AN ARM AND A LEG: DESIGNING LIMBS FOR MULTIPLE DYNAMIC BEHAVIORS

STUDENTS: JOSEPH SULLIVAN, AMBER CHOU, JOSHUA VASQUEZ

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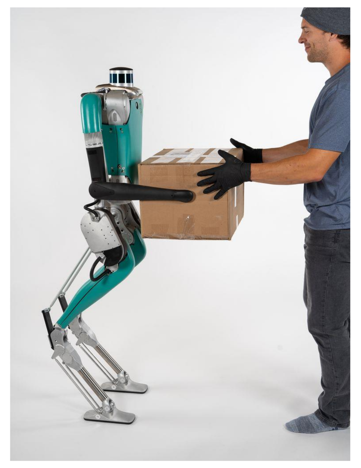
Near future applications for robots

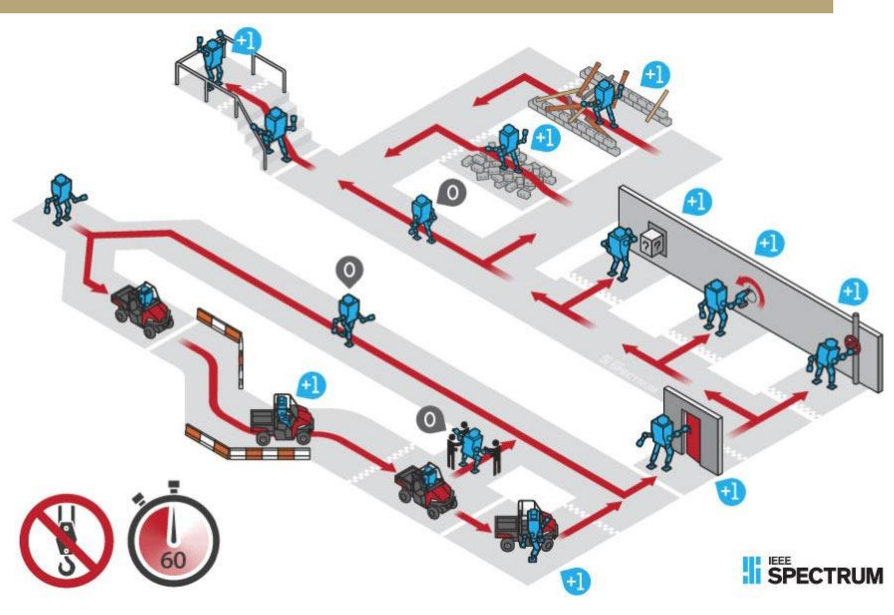




Requirements for robots of the future

Autonomy requires
- Traversing complex environments
- Operating for long periods

Versatility
- Doing many kinds of work
- Performing simultaneous locomotion and manipulation



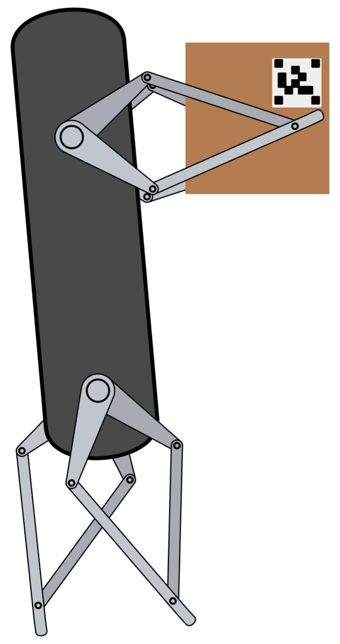
2015 DARPA Robotics Challenge Overview. Image from IEEE Spectrum Magazine.

State-of-the-art robots aren't up to the task

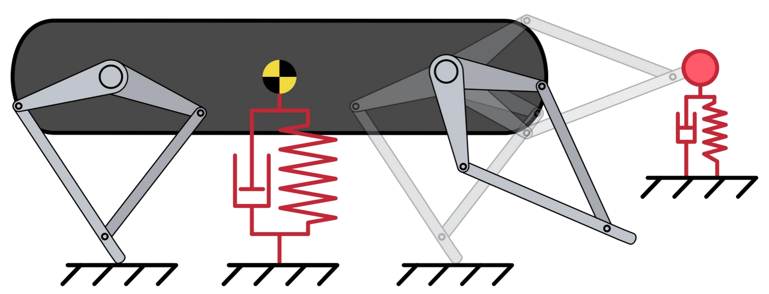

- For many years **research focused on locomotion.**
- Despite this, state-of-the-art **struggles with endurance.**
- Furthermore, **manipulation is treated post-hoc.**
- The result: robots have **limited autonomy and versatility**

Multi-behavior design methods are needed

- We seek **general** methods to design robots for multiple sets of behaviors.
- These methods should **provide a rational basis for design decisions and quantify tradeoffs** among behaviors.
- We propose employing those methods to design robots which **reuse limbs for locomotion** *and* **manipulation** tasks.



Example concept: a 4-limbed robot which performs tasks in bipedal and quadrupedal configurations. Each limb gets repurposed in the different behavioral regimes.



Design study: reusing a limb for hopping and weight-lifting

- The behaviors are respectively described by **dynamical systems** i.e.

$$\frac{d}{dt}\pi_y(x) = A\pi_y(x)$$

- We computationally optimize the limb by altering its **passive mechanics and mechanical advantage**.

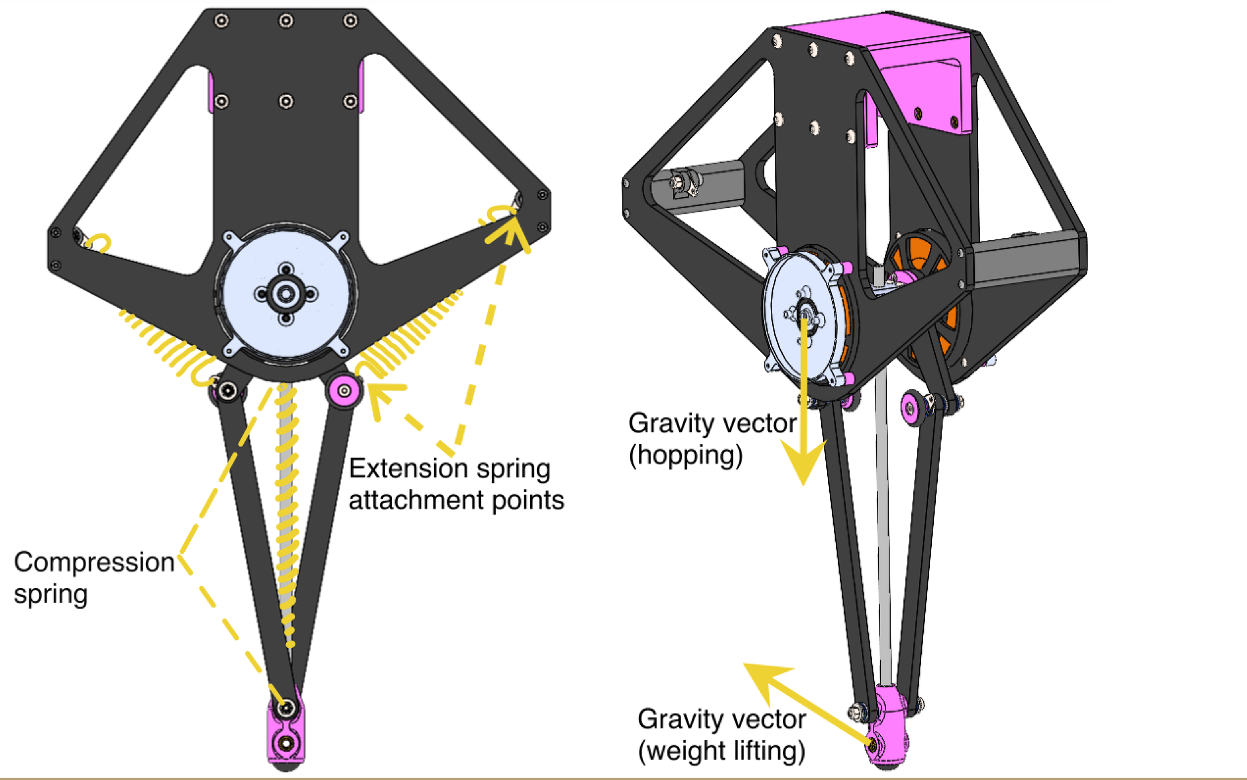
$$\frac{d}{dt}x = f_y(x) + g_y(x)u_y(x)$$

$$u_y(x) := (d\pi_y|_x g_y(x))^\dagger (A\pi(x) - f_y(x))$$

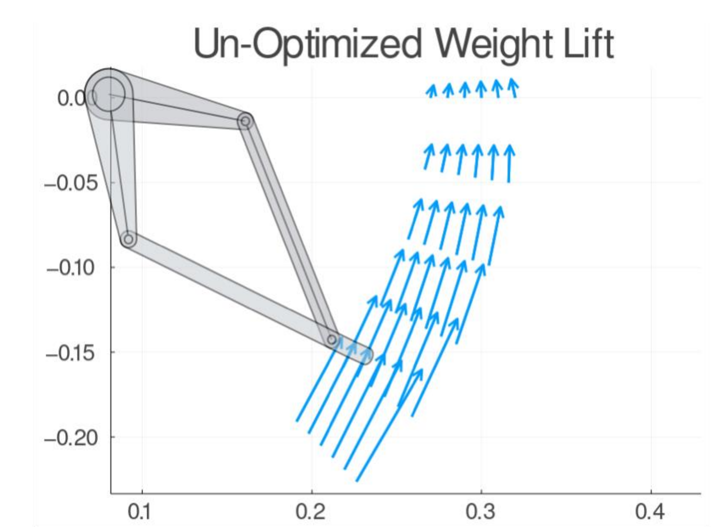
- Motivated by the need for endurance, we present an **electrical power metric** for evaluating designs.

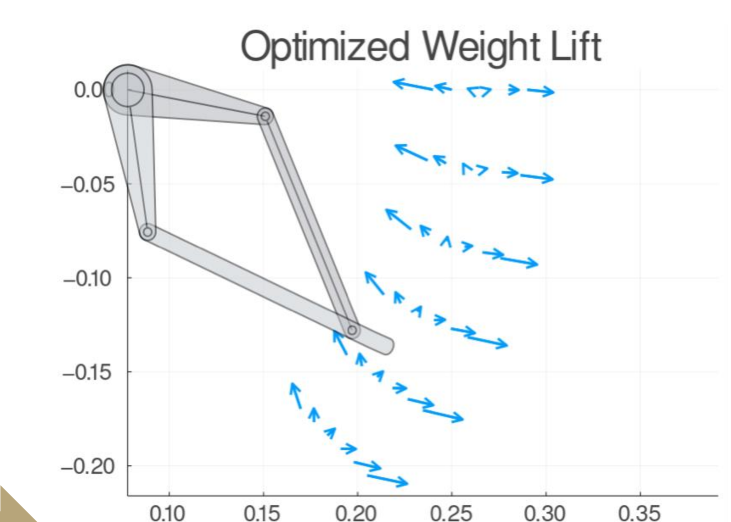
$$C(y) := \frac{1}{\mathrm{Vol}(\mathcal{D})}\int_{\mathcal{D}} ||u_y(x)||^2 dx$$

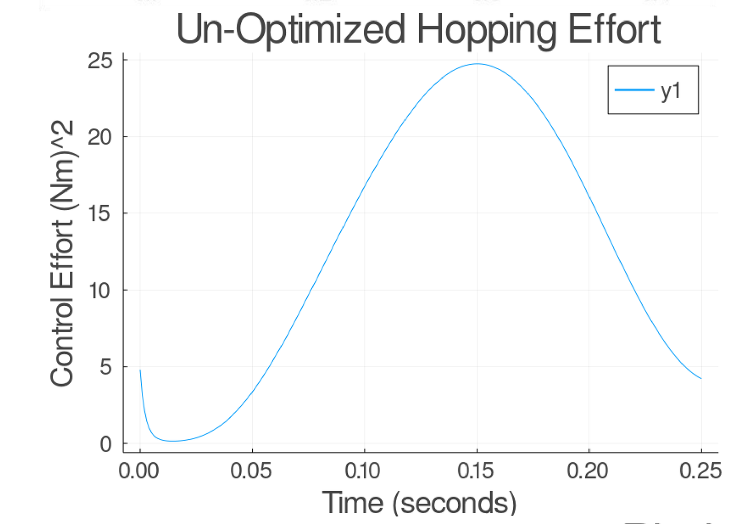
Design Concept

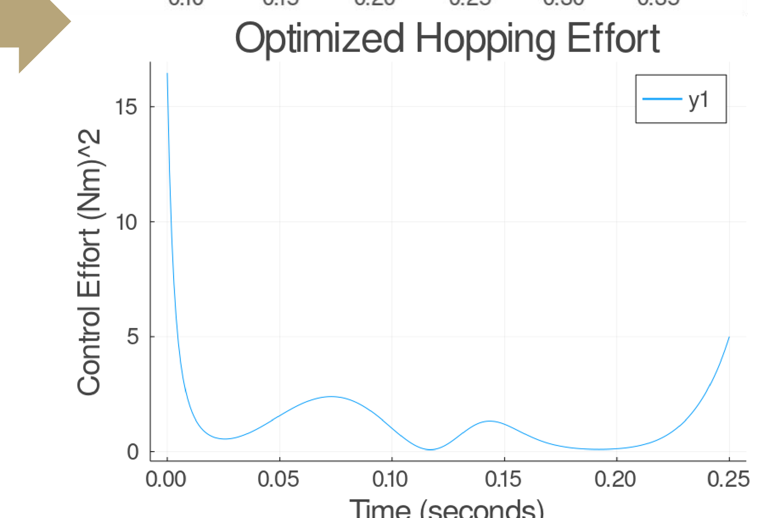


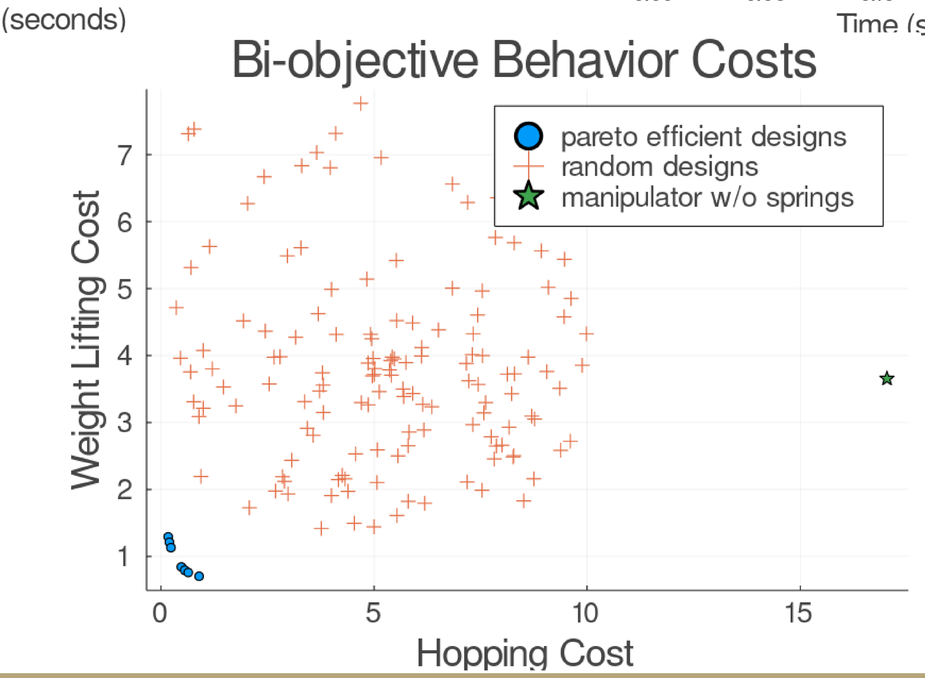
Computational Design Results











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