Inspiration from previous robots

We aim for:
- dynamic behaviors; high specific power
- more appendages (not more actuators)
- robust, compositional control
- morphology promoting energy transfer from battery to body

Inspiration from Biology

Tails are used for various purposes:
- inertial reorientation
- turning
- counter-act leg inertia in swing phase
- static balance
- quasistatic balance

Can we use a tail as the primary energizer?

Control as a parallel composition of templates

<table>
<thead>
<tr>
<th>Mode</th>
<th>Vertical hopping (VH)</th>
<th>Fore-aft (FA)</th>
<th>Shape</th>
<th>Pitch</th>
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<tbody>
<tr>
<td>Flight</td>
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<td>Stance</td>
<td>Tail &quot;wag&quot;</td>
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<td>Toe placement</td>
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<td>Tail torque</td>
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<td>Hip torque</td>
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Simulation return map shows that the tail-energization is stable and can control hopping height for a range of tail gains.

The fore-aft "acceleration" through stance shows the same monotonicity leveraged in [1]. (Simulation data)

Model for tail-energized 1-DOF vertical hopping; limit cycle and analytically-found trapping region (as in [2]).

Intriguing theoretical questions

- Subsystems analyzed in isolation in the past, but there is no analytical result guaranteeing success of parallel composition

Under what conditions does parallel composition of these decoupled controllers work?

Empirical demonstration on physical platform

- Preliminary prototype on planarizing boom
- 2 Kg platform, 180 W/Kg (peak output power)
- Implemented experiments with varying degrees of coupling
- Plots below are for the fully coupled system (4-DOF)

We borrow the idea of inertial reorientation in freefall from [3] and implement a simple PD servo with the tail torque that is available in flight.