Head and leg adjustments help insects and legged robots traverse cluttered, large obstacles

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**1. Background & Motivation**

Physical interaction (energy landscape) plays a major role during obstacle traversal

Model system → Locomotor transition pathways → Potential energy landscape

Othayoth et al. (in press), PNAS

Animals integrate active sensory feedback and passive mechanical feedback to control locomotion

Hypothesis: Cockroaches actively adjust body and appendages to overcome barrier and make transition

Awareness of landscape helps find a lower barrier

**2. Experimental Observations**

Beam obstacle traversal can be divided into three phases

<table>
<thead>
<tr>
<th>Run</th>
<th>Push</th>
<th>Roll</th>
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<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
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Cockroaches actively adjust their head and legs to make locomotor transition

3-D kinematics tracking setup

Leg sprawl, Differential leg use, Frequent head flexion

**3. Energy Landscape Modeling**

Energy landscape approach to understand physics of locomotor transitions

![Image](image4.png)

Proper head adjustment reduces energy barrier on landscape

Energy barrier comparison

Barrier is smaller with head bending than without (mean change < 0)

(P < 0.05, ANOVA)

**4. Robophysical Model & Future Work**

Legged robot to systematically control and vary active adjustment of head and legs

Legged robot, Leg sprawl, Differential leg use, Head flexion

Preliminary result: all the three adjustments help the robot roll into the gap

Next steps

Robot with force sensors → Embedded sensors at the neck → Low cost 3-axis force sensor (designed by J. Krakauer's group)

Force measurements to understand:
- Relationship between contact forces and potential energy landscape (slope?)
- Transitions on landscape emerging from local force sensing

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