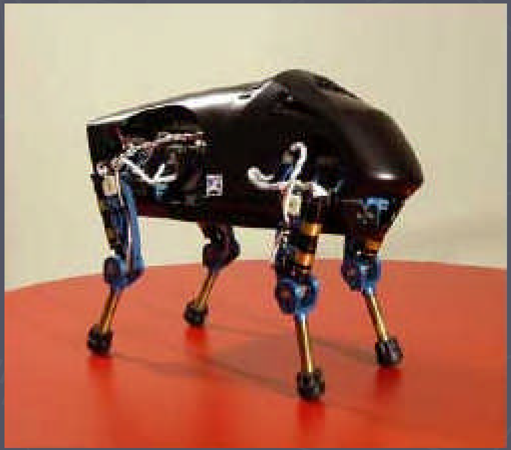
Learning Legged Locomotion Over Extreme Terrain



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Basis for the Project

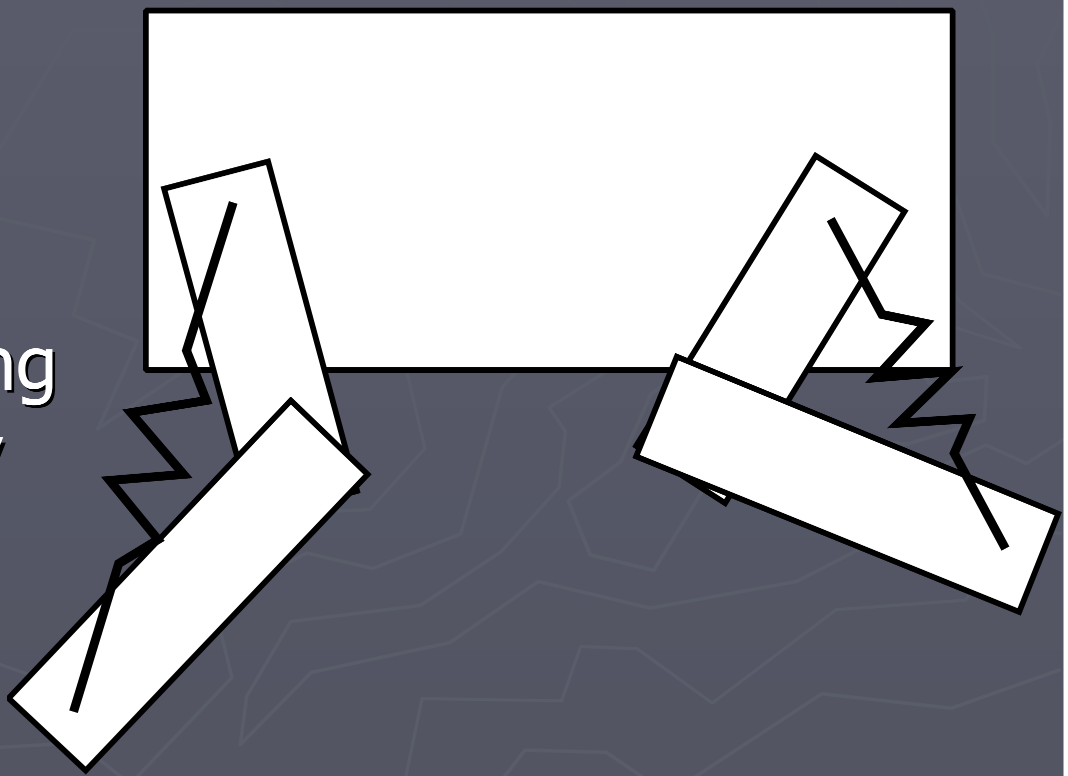
- DARPA solicitation BAA 05-25: learning autonomous locomotion over obstacles
  - "No-Go" to "Slow-Go"
- Problem is highly complex, due to frictional contacts and degrees of freedom
- Project goal was to find a way to represent "good" steps in a lower-dimensional space, and to demonstrate these steps on an actual quadruped (Sony Aibo) scaling a 1-2" step

Overview of Step Method

- Potential Fields used to translate and rotate torso
- Footfalls pre-sequenced to just allow foot contact at surfaces
- Torso moves relative to the feet, not the feet relative to the torso (no return stroke required in footpaths)

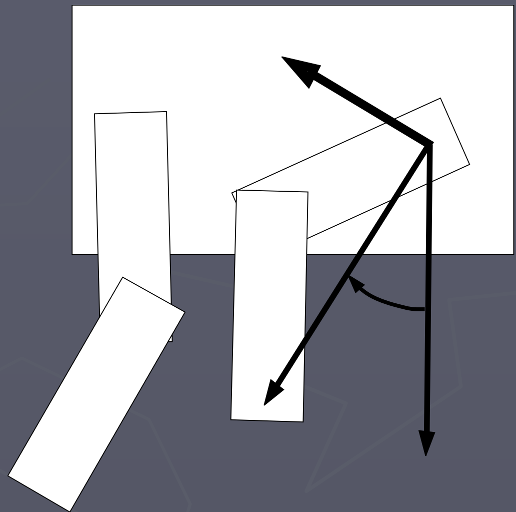
Potential Fields: 1. Radial Field

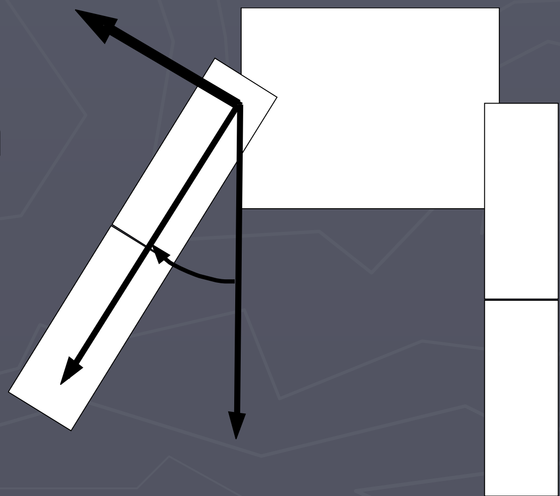
- Nicknamed “shock absorber” system
- Stretching foot outwards pulls torso along “spring”, pulling foot in close to body pushes torso away
- Keeps feet within their configuration spaces



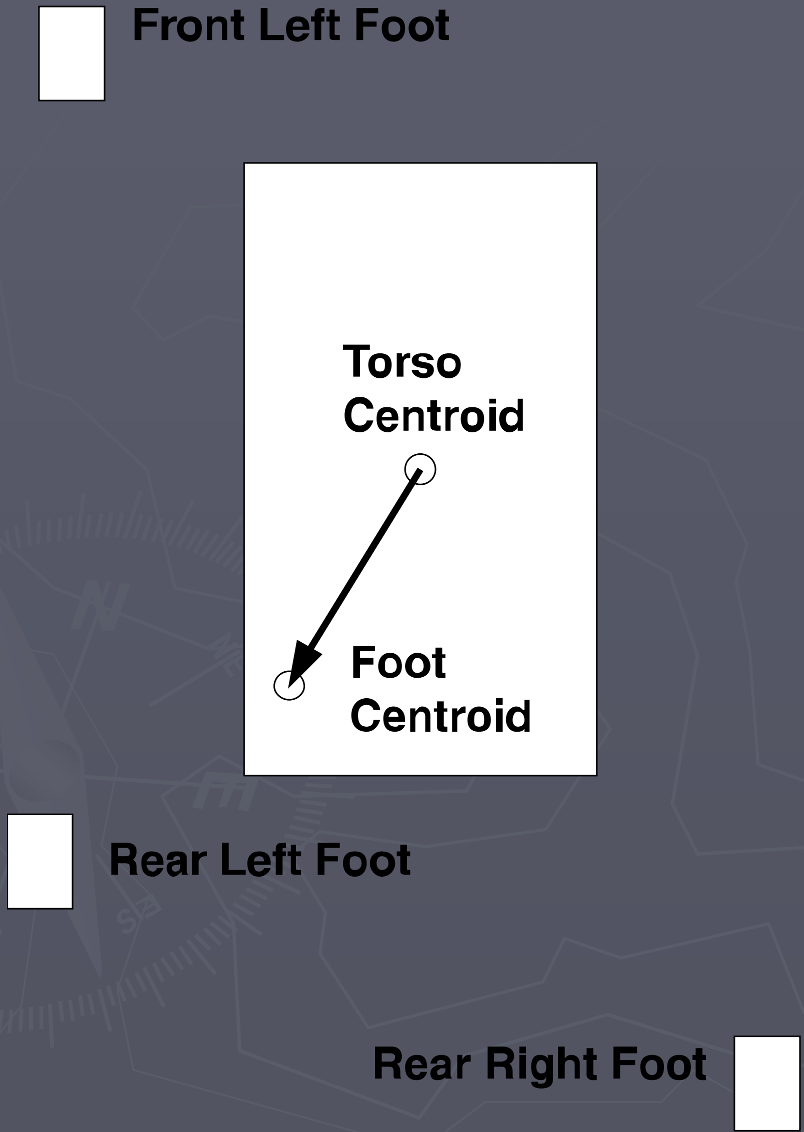
Potential Fields: 2. Angular Field

- Push torso to keep leg angles within mechanical limits
- Decomposed into two fields: “flap” and “swing”
- Direction of force application perpendicular to radial field





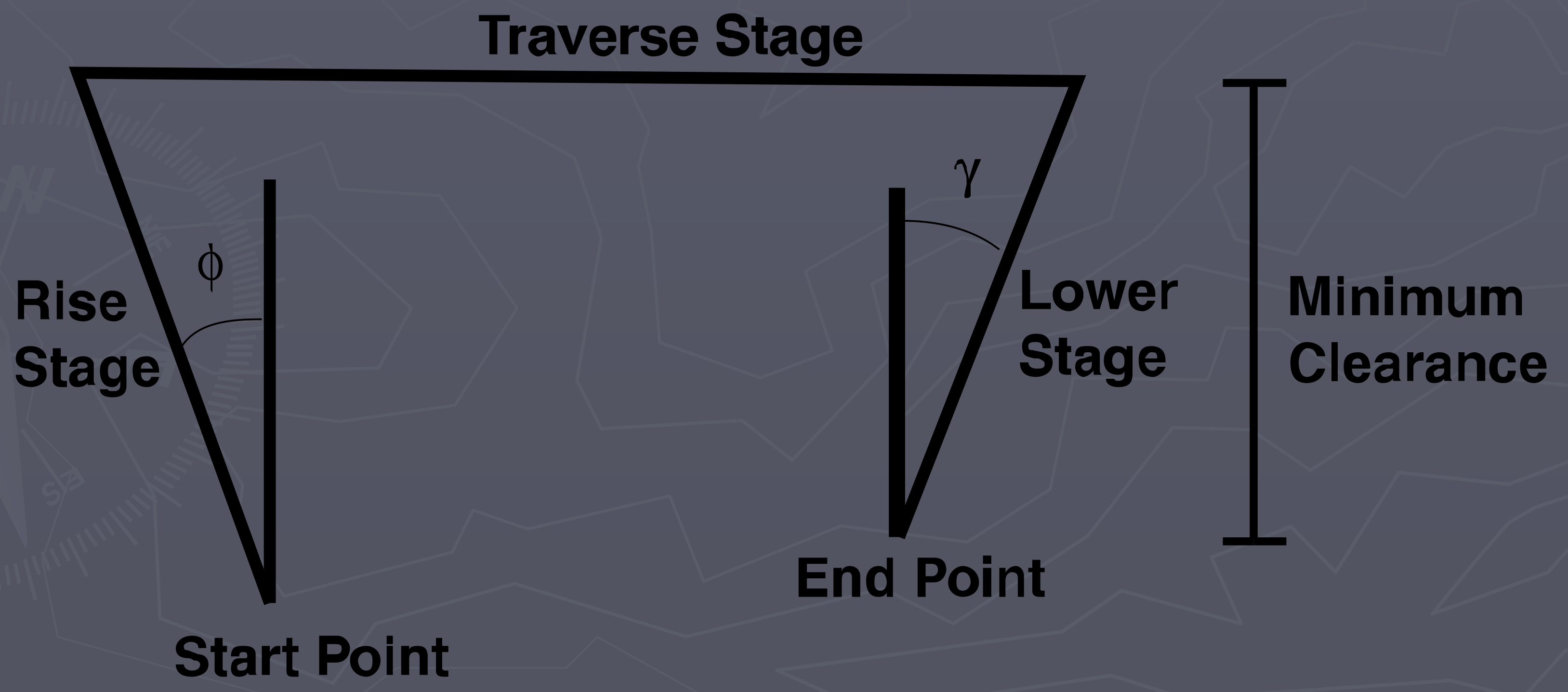
Potential Fields: 3. Balance Field



- Keeps the torso within the polygon determined by the planted feet
- Pull-toward-center field

Explanation of Leg Paths

- Trapezoidal steps used since claw disengagement was necessary
- No return stroke, since already implicit in torso's movement relative to feet

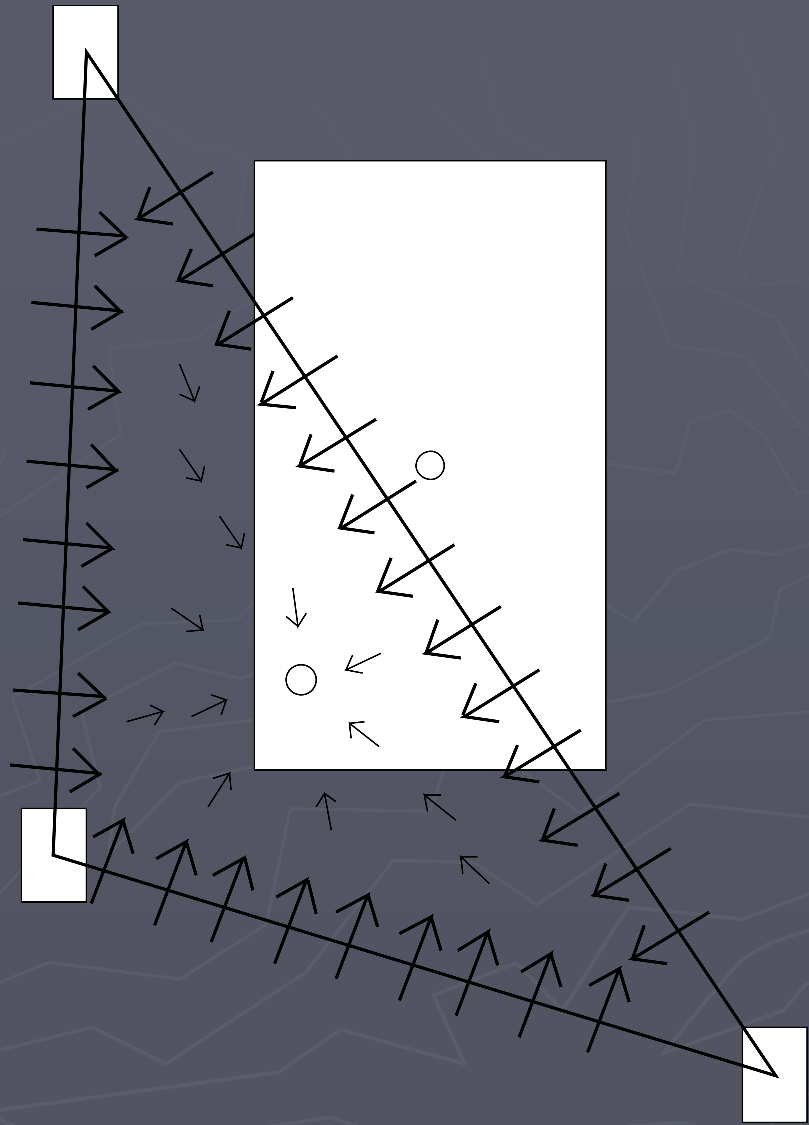


Primitives and Footfall Sequences

- Act of scaling step broken into three primitives: Front-Up, Move-Forward, Rear-Up
- Different field tuning, different footfall sequences for each primitive
- Proper footfall sequences found to be crucial for performance

Future Work

- Method for determination of footfall sequences and step displacements
  - Missing piece to work done so far
- Learnable primitive generation and switching
- Improvements to field system



Future Work (cont.)

- 6-DOF Quaternion formulation
- Computational Optimization
  - Closed-Loop locomotion requires step calculation at runtime
- Extreme Dynamic Locomotion
  - Two feet on ground at a time
  - Faster steps and higher performance, in principle

Summary

- Torso field and pre-set step system has proven successful in climbing 35 mm and 50 mm (0.35 L) steps
- Substantial work remains in developing footfall determination algorithms, automatic primitive switching, methods for executing extreme dynamic gaits