Legged Robotics & BigDog

Marc Raibert: Boston Dynamics

Andy Schmidt

University of North Carolina at Charlotte

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Raibert's Legged Robotics Paper

Why Legged Machines?

1. Traverse difficult train
   - Wheels excel on prepared surfaces
   - Legs allow travel to more remote areas
2. Active suspension of body from feet
   - Body travels "smoothly" despite variations in terrain
   - Legged system can choose among best footholds
   - Do not need constant contact with surface

Raibert's Legged Robotics Paper

Pitfalls:

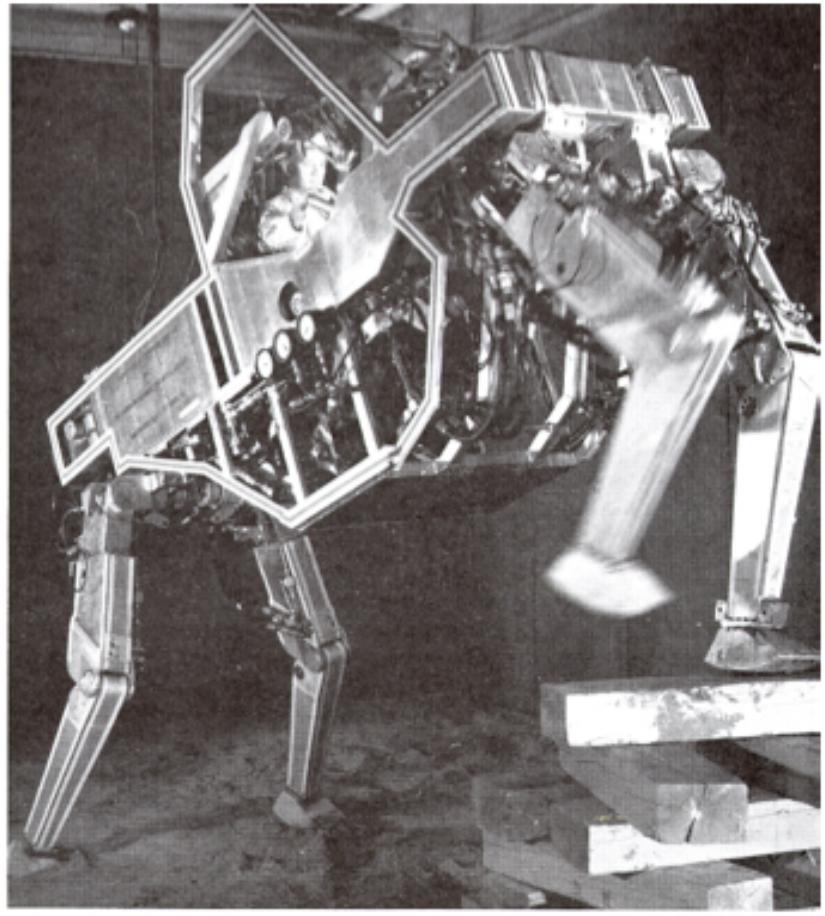
- Joint movement
- Balance
- Current and future foothold calculations

Legged Robotics - History

- 1870s - Simple walking machines
- 1960s - Human Control (I.E. GE Legged Truck)
- 1970s - Computer Control (Ohio State University - 1977)
- **Linkages** to provide appropriate stepping motions
- Limitation: No *Control* - Best footholds

Static Balance: Some feet on ground to guarantee support

General Electrical Legged Truck



Legged Robotics - Active Balance

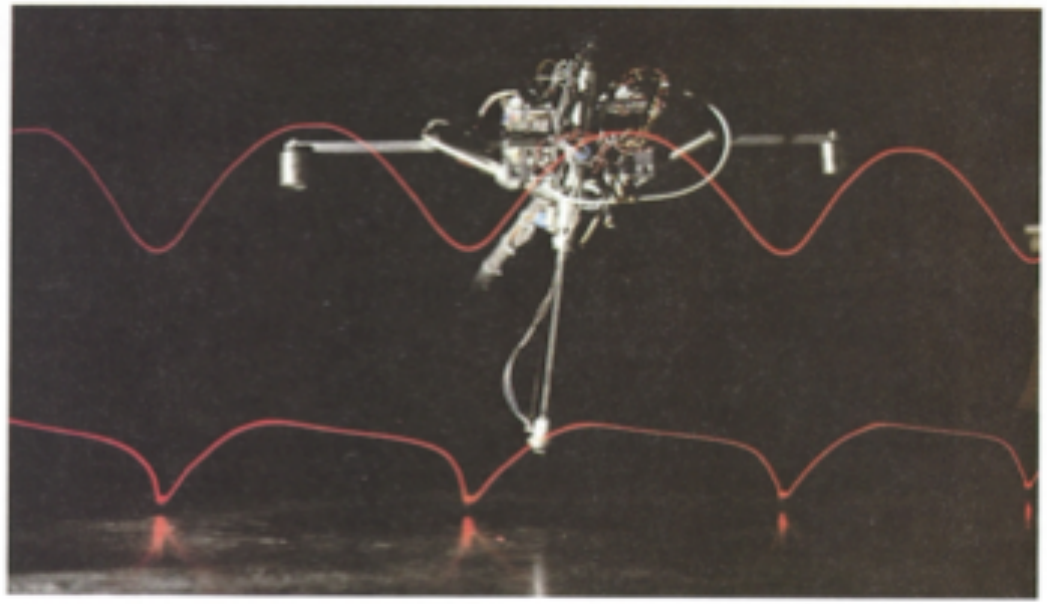
Active Balance: Legged systems operating while considering velocities and kinetic energies of the masses

- Challenges:
  - Energy stored in each mass and spring
  - Geometric structure and configuration
  - Velocity
- Running with respect to Active Balancing
- Tip and accelerate (short) then tip in opposite direction
- An effective base (balance) is maintained over time
- Result: Improved mobility

Legged Robotics - Running Machines

- Running Cycle:
  - **Stance** Leg supports weight of body
  - **Flight** Center of mass moves ballistically allowing unloaded leg to move freely
- Running Control:
  - **Hopping** Delivered vertical thrust with the leg during each support period to sustain oscillation and regulate amplitude
  - **Forward Speed** Calculate the next foot position (angle) which plays into the speed
  - **Posture** Stabilize pitch angle of body to keep it upright

Marc Raibert's One Legged Robot



Legged Robotics - From One to Four Legs

- Bi-beds run with alternating support and flight
- One leg is placed on the ground at a time
- **Virtual Leg**: Group of legs with simultaneous support
- One *virtual leg* provides support / flight at a time
- Trotting quadruped = biped = one-legged machine

Boston Dynamics

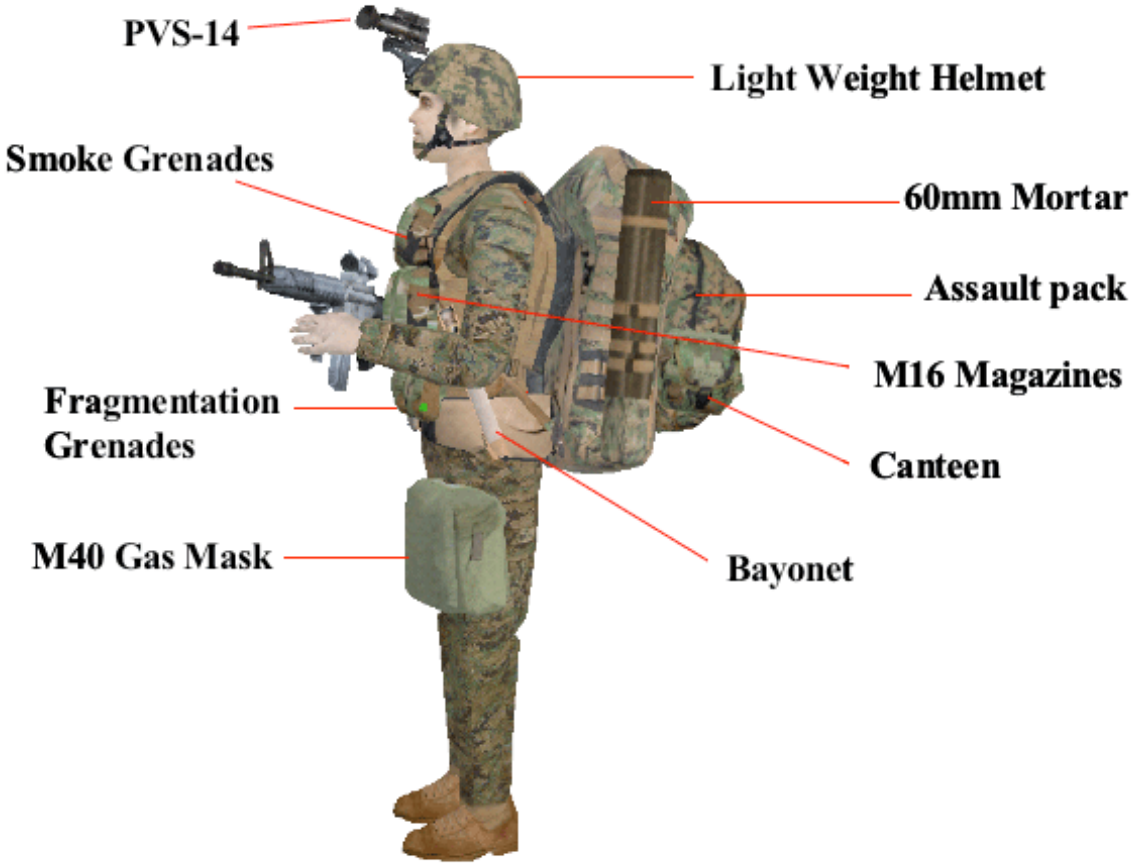
- Started by Marc Raibert (MIT) in 1992
- Focus on Human Simulation and Robotics

Sony	Entertainment Robots
Army	Institute for Creative Technologies
Marines	Marine Expeditionary Rifle Squad

- Robotics:

BigDog	Quadruped Robot
LittleDog	Legged Learning Robot
RHex	Remote Controlled Terrain Robot
RiSE	Climbing (as in vertical!) Robot

Boston Dynamics - DI Guy



Boston Dynamics - BigDog

Requirements:

- Capable of running
- Jumping over objects 1 meter tall or 2 meters wide
- Traverse a variety of terrain
- Operate for two hours without refueling

Boston Dynamics - BigDog

BigDog Stats:

Size	1 meter long $\times$ 0.7 meters tall
Weight	75 Kg
Power	One Cylinder Gas engine and battery
Hydraulic Actuators	3 joints repositioned up to 500/sec
Speed	4 mph
Climbs	35–45°
Load	155 Kg
Contract	$40 Million+ from DARPA

Boston Dynamics - BigDog

Boston Dynamics - BigDog

Sensors

- Joint positioning
- Joint force
- Ground contact
- Ground load
- Laser gyroscope
- Stereo vision system
- Internal sensors monitoring:
  - Hydraulic pressure
  - Oil temperature
  - Engine temperature
  - RPMs
  - Battery charge

Boston Dynamics - BigDog

Future goals:

- Follow a solider
- Allow solider to specify distance to follow
- Move to solider to provide supplies
- Deviating from the soldiers path
- Move faster, longer, and be stronger!