# Biped and Quadruped Running

*Chapter 4 presented by Jan Peters*

# Motivation

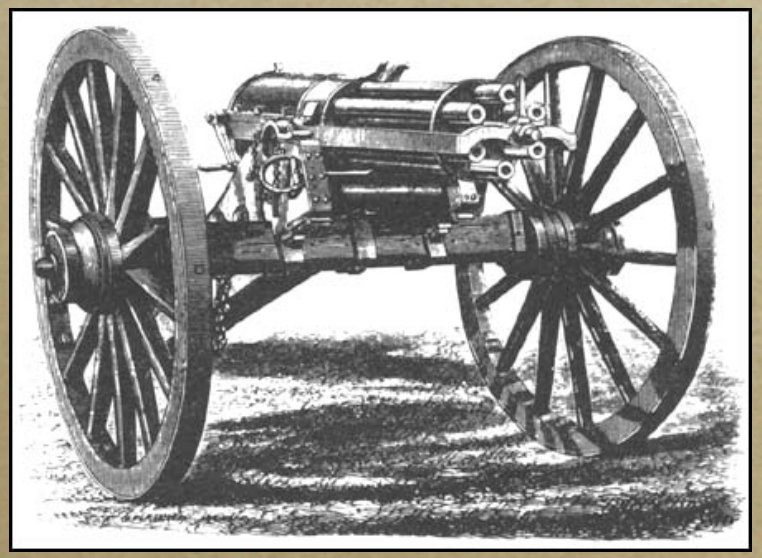

- *We have learned how to hop on one leg in Chapters 2-3.*
- *How does this generalize for multiple legs?*
- *Raibert suggests: decompose multiple leg walking into components we understand.*

# Outline


1. ***One-Foot Gait****: Run as if you hop…on more legs…*
2. ***Virtual Legs****: Use many legs as one!*
3. ***Summary***

# 1 One-Foot Gait


- *Can multi-leg walking be modeled as a **Gatling Gun?***



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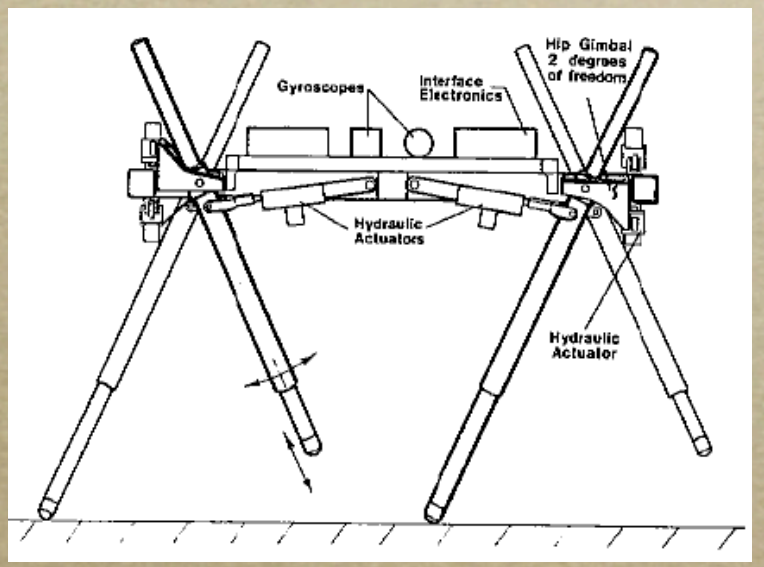


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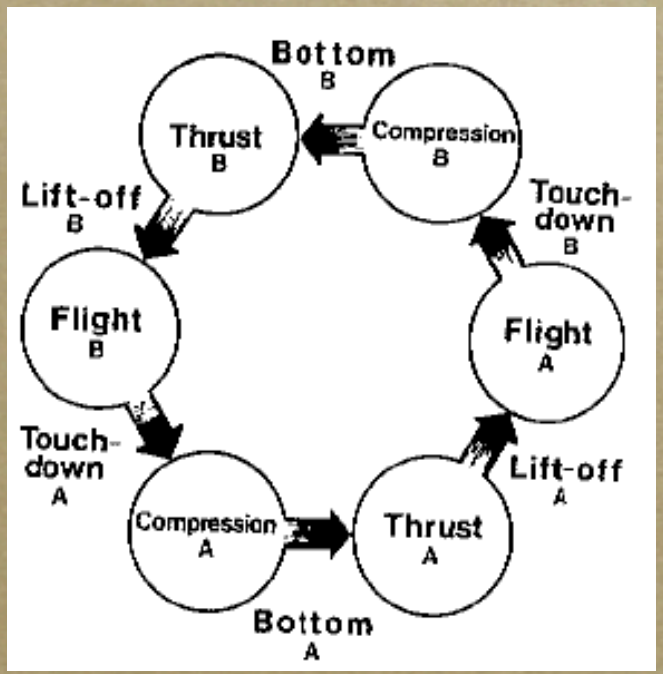
*Legs=Barrels? Only an American can think of that!*

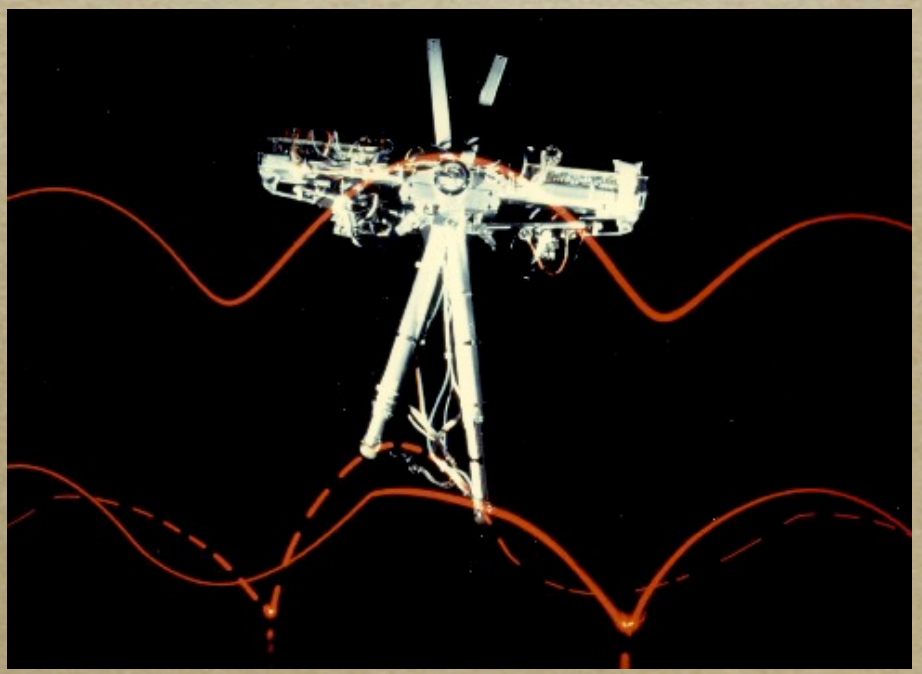
# 1 One-Foot Gait Definition


- ***Definition***:
  1. ***Barrel firing***: *one leg provides support at a time.*
  2. ***Barrel moving***: *support phases and flight phases strictly alternate.*
- ***Note***: *Adult humans run with a one-foot gait!*

# 1 Planar Biped Running

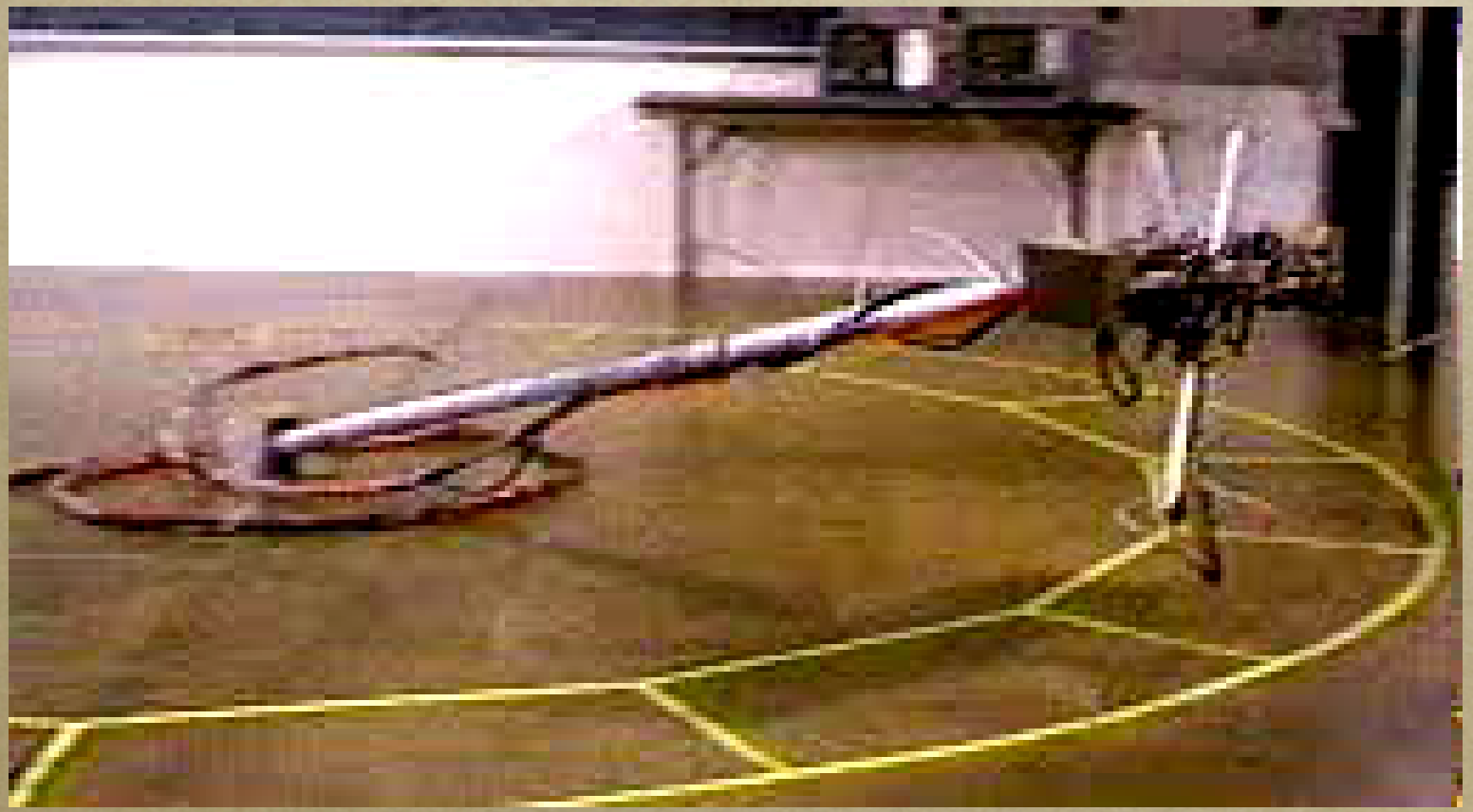

- *Control both legs as in the one-legged case.*
- *Use a sequencing mechanism to coordinate both legs!*



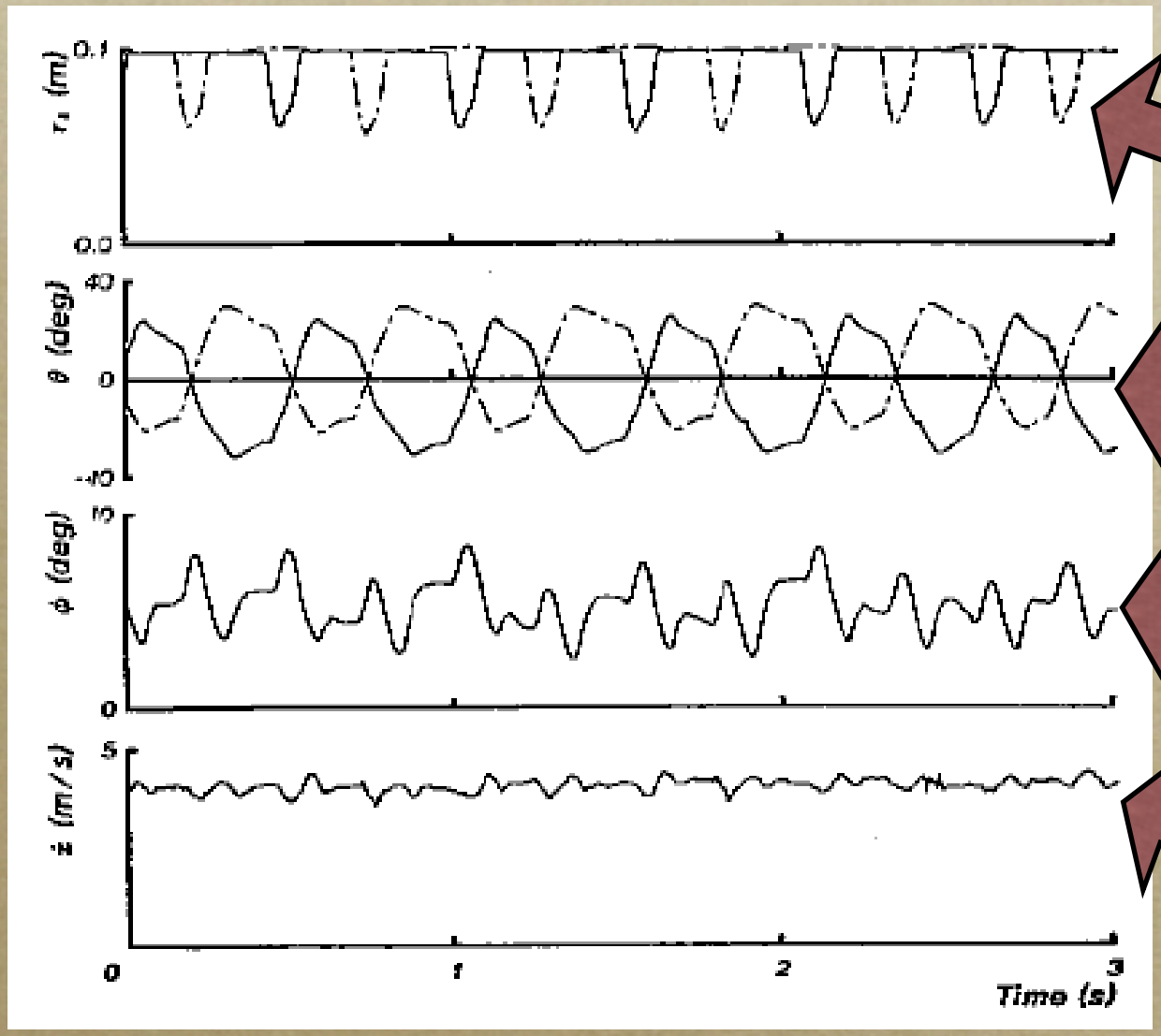



# 1 Planar Biped Running


***BIPED RUNNING CAN BE REDUCED ON HOPPING!***



# 1 Planar Biped Running


*Compression of the air springs*

*Angle of legs vs vertical*

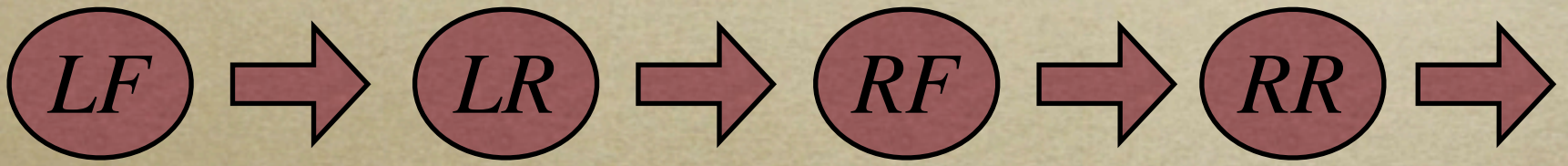
*Pitch*

*Forward speed*

# 1 Quadruped Running?


***Would this also work for quadrupeds?***

- *Intuitively: YES, just cycle through the legs:*




- ***But:*** *sequencing has too much choice, and to get the other legs out of the way!*
- *Practical problem: mounting the legs close enough to the center of mass.*
- *Special cases:bending spine&symmetry(C.5)*

# Outline


1. ***One-Foot Gait****: Run as if you hop...on more legs...*
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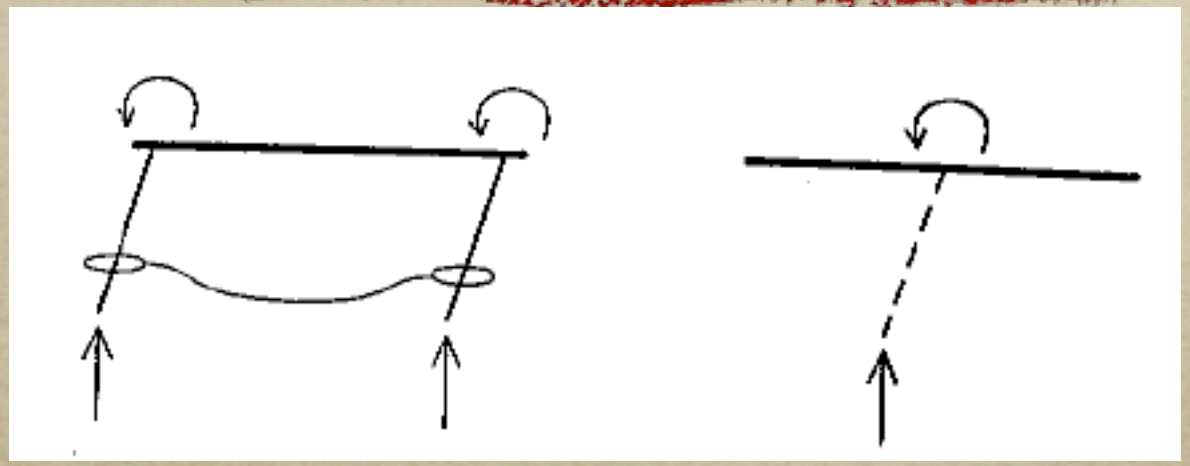
# 2 Virtual Leg Concept


*Two legs can act as one!*



*Invented by Sun Founder Ivan Sutherland*

# 2 Operations


***Operations on physical legs for generating virtual behaviors:***

1. *Positioning: Choose physical feet position to generate virtual foot position.*
2. *Synchronization: Touchdown &lift-up at the same time!*
3. *Force equalization: Develop equal axial force to ground!*

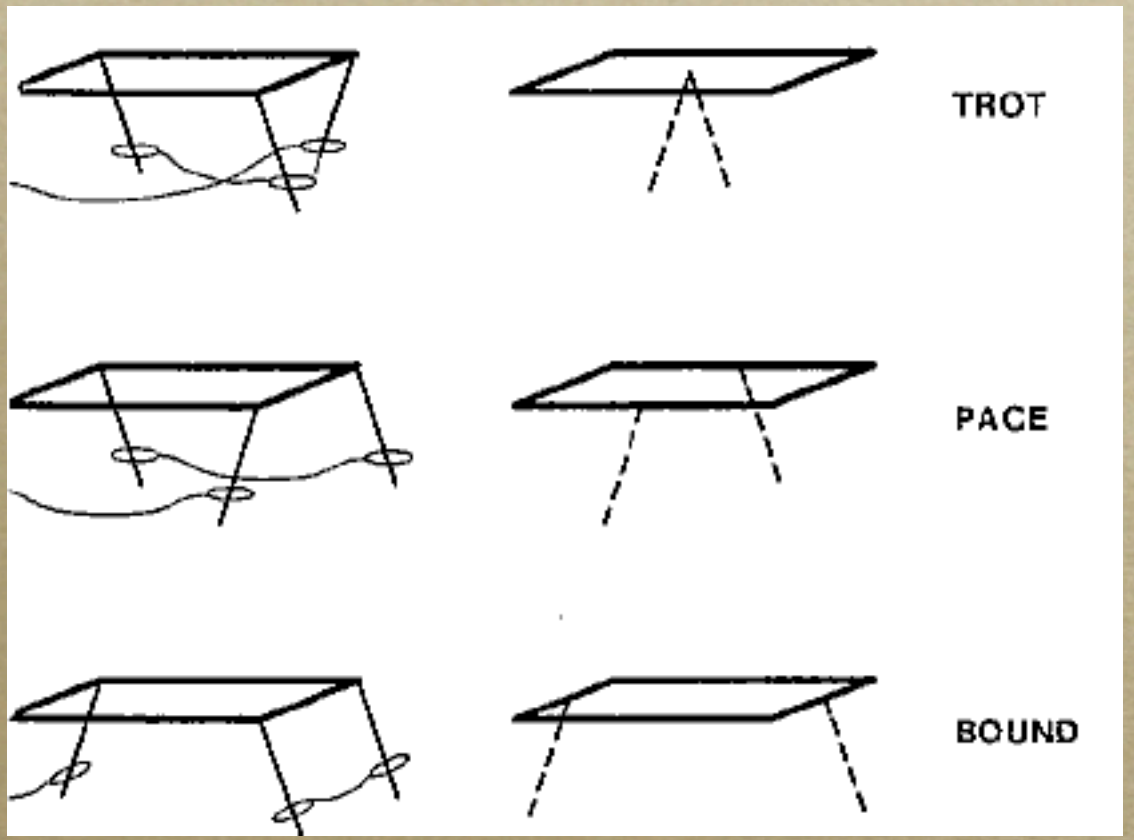
# 2 Virtual Leg Concept


**COOL:**

**QUADRUPED = TWO VIRTUAL LEGS = VIRTUAL BIPED**

**But trades passive against active stability...**

# 2 Trot, pace, bound


*COOL! Trot, pace and bound can be expressed using*

2

# Trot


2

# Pace


2

# Bounce


# Outline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3

# The Quadruped


- *One leg locomotion control algorithms can be extended to multiple leg algorithms.*
- *One-Foot Gaits suffice for bipeds!*
- *Sequencing is the main problem fro applying one-foot gaits to N-feet machines...*

3

# Summary


- *Virtual legs solve this problem.*
- *Allow it to treat a quadruped as a biped!*
- *Virtual legs can be mapped into trot, pace and bound...*
- *But: they give up passive stability towards active stability!*

# That's all folks!


**Any Questions before we ride off into sunset?**