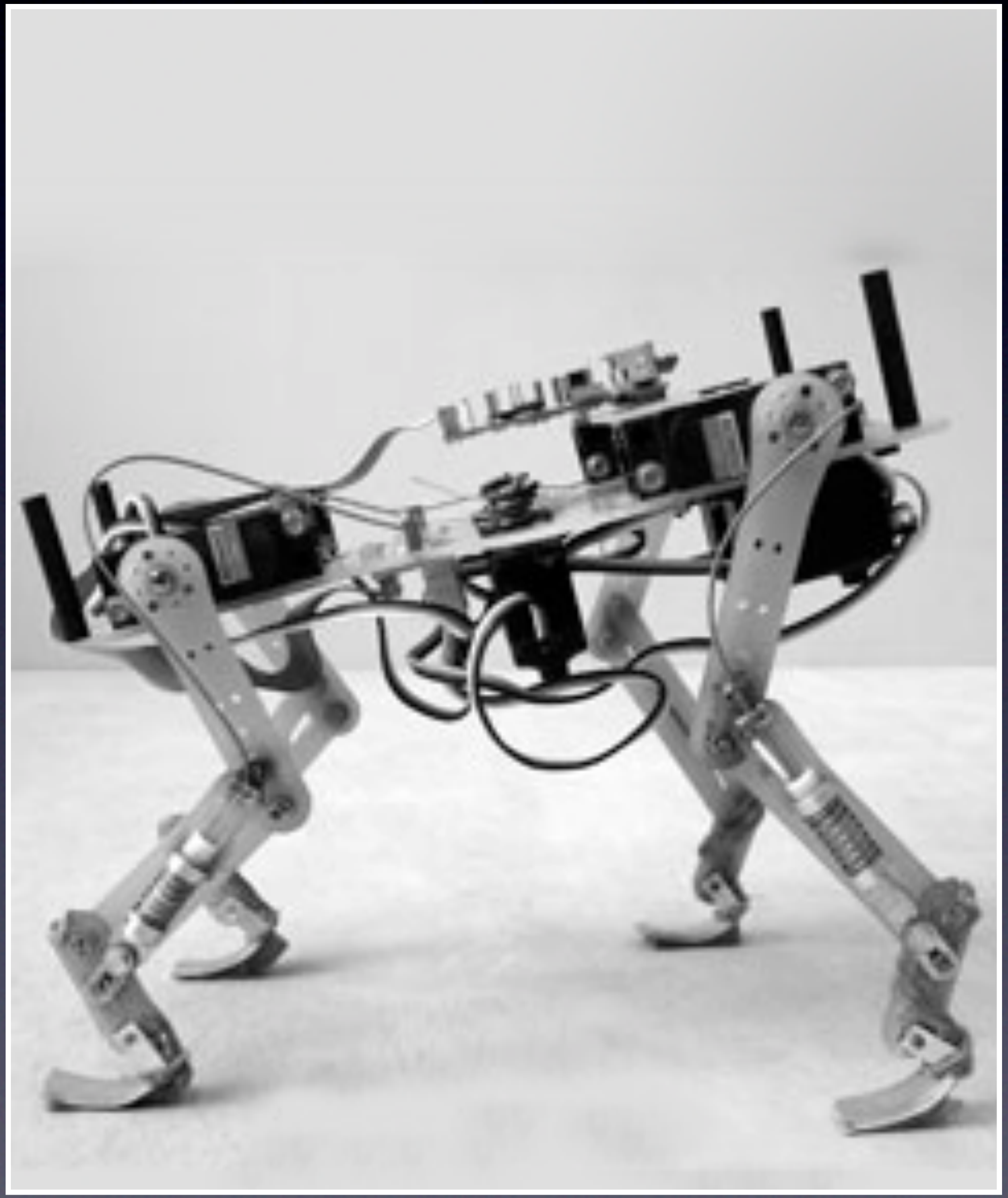
Improvement of the Cheetah Locomotion Control

Master Project - Midterm Presentation

3rd November 2009

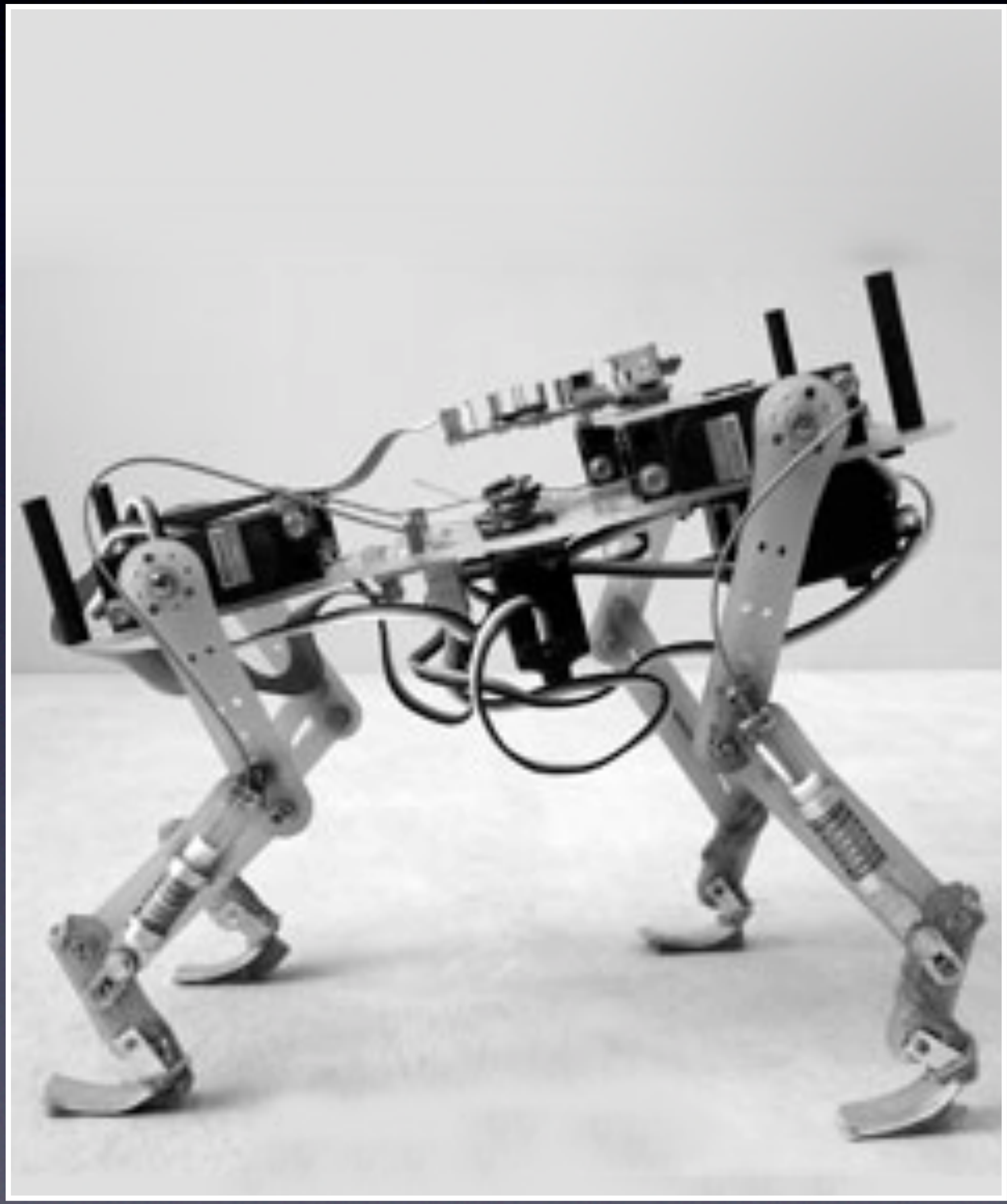
Student : Alexandre Tuleu
Supervisor : Alexander Sproewitz
Professor : Auke Jan Ijspeert

Presentation of the Cheetah



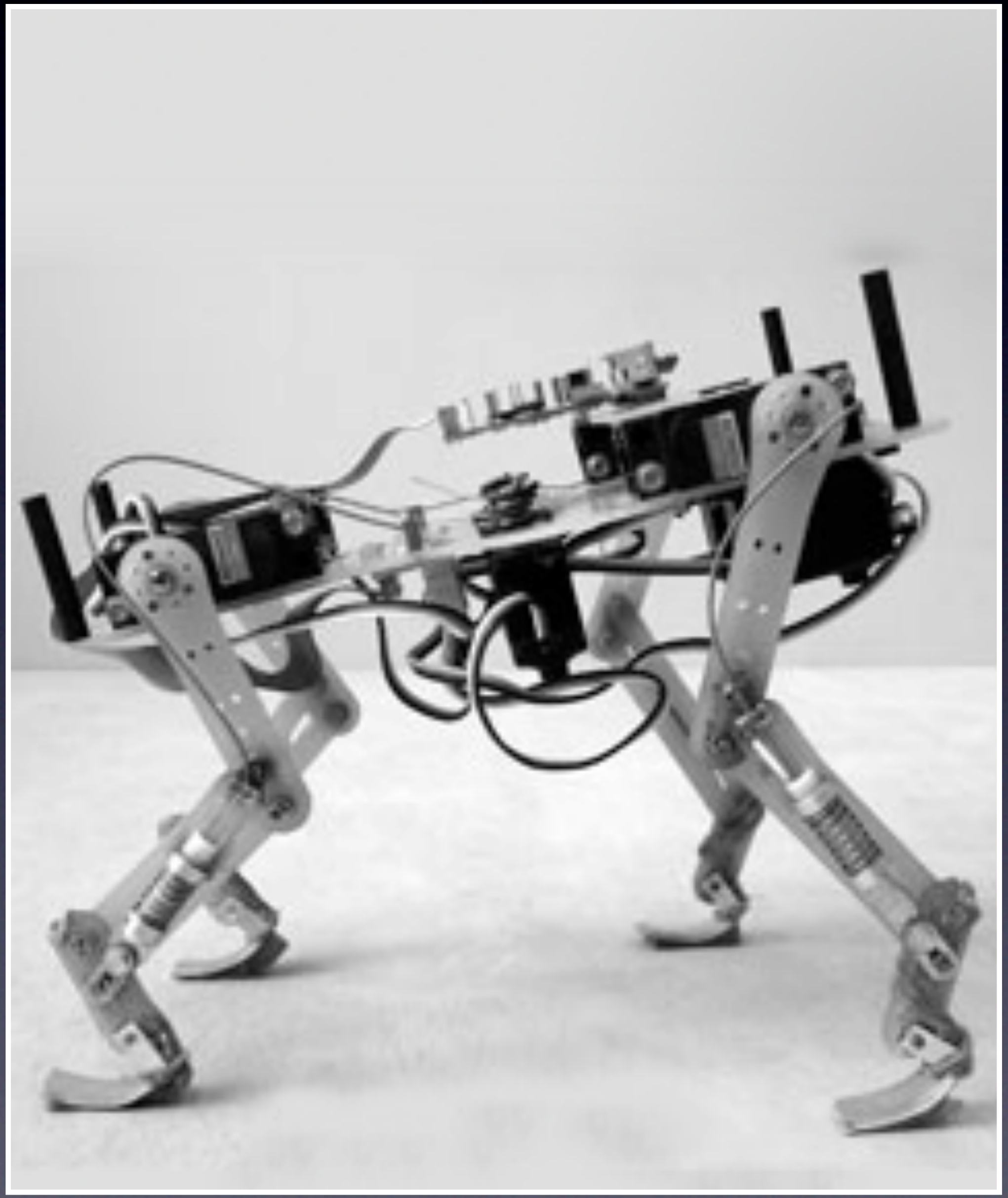
Presentation of the Cheetah

- Light weighted, biollogically inspired small quadruped robot



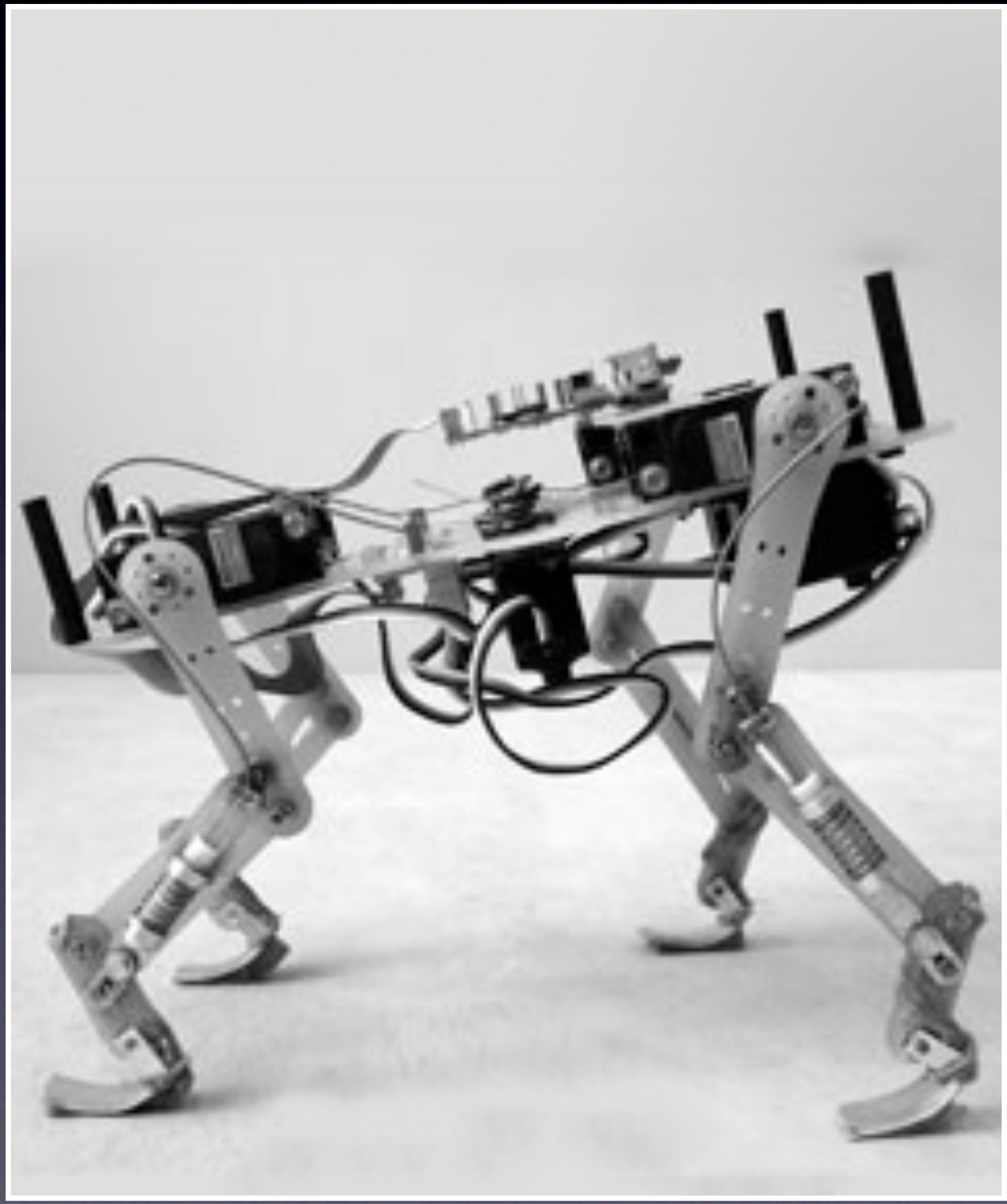
Presentation of the Cheetah

- Light weighted, biollogically inspired small quadruped robot
- Pantograph, compliant legs



Presentation of the Cheetah

- Light weighted, biollogically inspired small quadruped robot
- Pantograph, compliant legs
- Leg design and proportions chosen from characteristic values for Mammals.



Goals of the project

Goals of the project

- Improve the locomotion control in term of efficiency, Robustness and controllability

Goals of the project

- Improve the locomotion control in term of efficiency, Robustness and controllability
- Model mechanic improvement, and measure their effect on the locomotion behavior :
  - New foot design
  - Adding a scapula joint
  - Adding a spinal coord
  - Test different leg segmentation and connections ...

Table of contents

Table of contents

Table of contents

Table of contents

- Locomotion Behavior in Nature
- Timeline of the project
- Work done
  - Update of the webots model

Table of contents

Three Self-Stabilization Principles

[Seyfarth03] **Swing Leg Retraction: a simple control model for stable running**, André Seyfarth and Hartmut Geyer, *Journal of experimental Zoology* 206:2547-2555 (2003)
[Daley09] **The Role of Intrinsic muscle mechanics in the neuromuscular control of stable running in the guinea fowl**, *Journal of Physiology* 587.11 (2009) pp 2693-2707
Video Extract : Youtube

Three Self-Stabilization Principles

Self-Stabilization

Passive capacity to stabilize in open loop process (no sensory feed back as a response to internal or external disturbance)

[Seyfarth03] **Swing Leg Retraction: a simple control model for stable running**, André Seyfarth and Hartmut Geyer, *Journal of experimental Zoology* 206:2547-2555 (2003)
[Daley09] **The Role of Intrinsic muscle mechanics in the neuromuscular control of stable running in the guinea fowl**, *Journal of Physiology* 587.11 (2009) pp 2693-2707
Video Extract : Youtube

Three Self-Stabilization Principles

Self-Stabilization

Passive capacity to stabilize in open loop process (no sensory feed back as a response to internal or external disturbance)

- Leg Stiffening

[Seyfarth03] **Swing Leg Retraction: a simple control model for stable running**, André Seyfarth and Hartmut Geyer, *Journal of experimental Zoology* 206:2547-2555 (2003)
[Daley09] **The Role of Intrinsic muscle mechanics in the neuromuscular control of stable running in the guinea fowl**, *Journal of Physiology* 587.11 (2009) pp 2693-2707
Video Extract : Youtube

Three Self-Stabilization Principles

Self-Stabilization

Passive capacity to stabilize in open loop process (no sensory feed back as a response to internal or external disturbance)

- Leg Stiffening
- Leg Retraction [Seyfarth03]

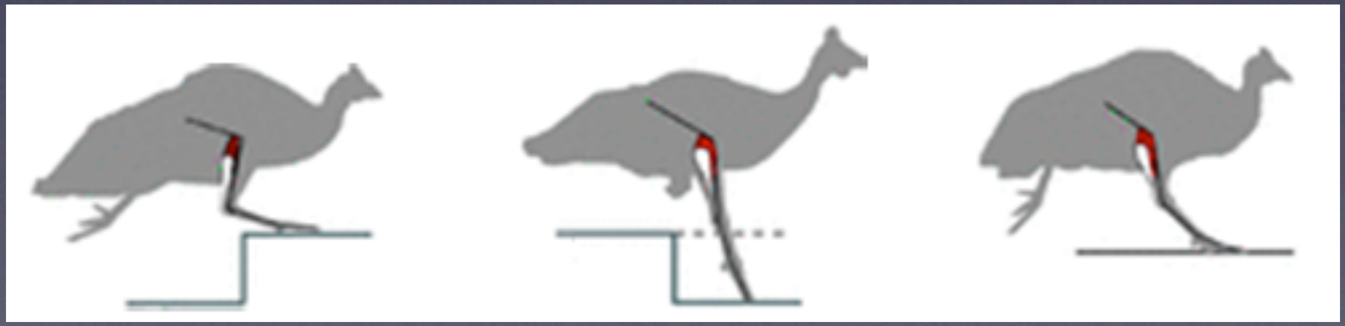
[Seyfarth03] **Swing Leg Retraction: a simple control model for stable running**, André Seyfarth and Hartmut Geyer, *Journal of experimental Zoology* 206:2547-2555 (2003)
[Daley09] **The Role of Intrinsic muscle mechanics in the neuromuscular control of stable running in the guinea fowl**, *Journal of Physiology* 587.11 (2009) pp 2693-2707
Video Extract : Youtube

Three Self-Stabilization Principles

Self-Stabilization

Passive capacity to stabilize in open loop process (no sensory feed back as a response to internal or external disturbance)

- Leg Stiffening
- Leg Retraction [Seyfarth03]
- Leg Extension [Daley09]



[Seyfarth03] **Swing Leg Retraction: a simple control model for stable running**, André Seyfarth and Hartmut Geyer, *Journal of experimental Zoology* 206:2547-2555 (2003)
[Daley09] **The Role of Intrinsic muscle mechanics in the neuromuscular control of stable running in the guinea fowl**, *Journal of Physiology* 587.11 (2009) pp 2693-2707
Video Extract :Youtube

Other locomotion "blueprints"

[Fisher06] **The Tri Segmented Limbs of Therian Mammals: Kinematics, Dynamics, and Self-Stabilization-A Review**, Martin S. Fisher and Reinhard Blickhan, *Journal of experimental Zoology* 305A:935-952 (2006)
Video Extract : Youtube & BBC

Other locomotion "blueprints"

- Wrist linkage and compliance

[Fisher06] **The Tri Segmented Limbs of Therian Mammals: Kinematics, Dynamics, and Self-Stabilization-A Review**, Martin S. Fisher and Reinhard Blickhan, *Journal of experimental Zoology* 305A:935-952 (2006)
Video Extract : Youtube & BBC

Other locomotion “blueprints”

- Wrist linkage and compliance

- Use More Sagital bending of Spine than proximal articulation in assymetrical running gait. [Fisher06]

[Fisher06] **The Tri Segmented Limbs of Therian Mammals: Kinematics, Dynamics, and Self-Stabilization-A Review**, Martin S. Fisher and Reinhard Blickhan, *Journal of experimental Zoology* 305A:935-952 (2006)
Video Extract :Youtube & BBC

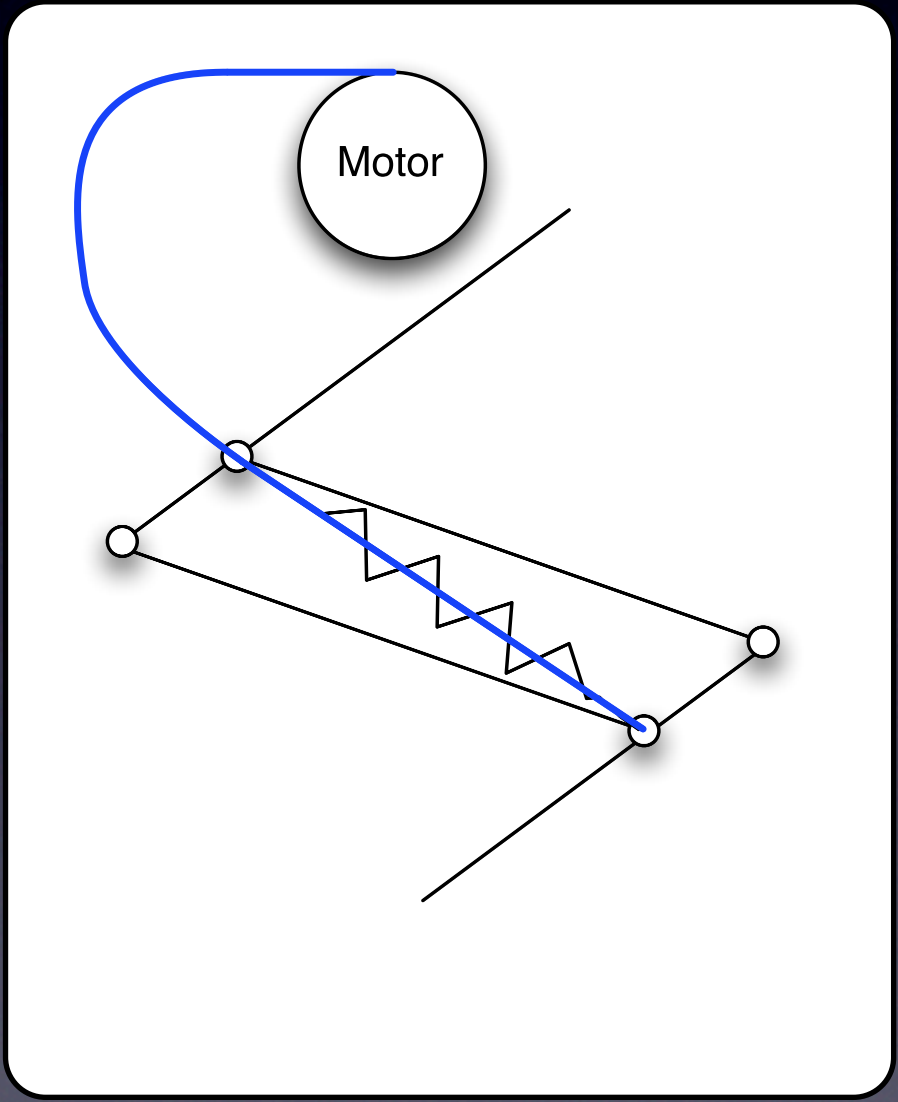
Timeline

Model Update		Design of the control		Testing Mechanical Improvement		
Fix Webots Model	Prepare optimization framework	Foot trajectory definition	Gait Optimization	New Foot	New Scapula Joint	Sipnal Cord

Timeline

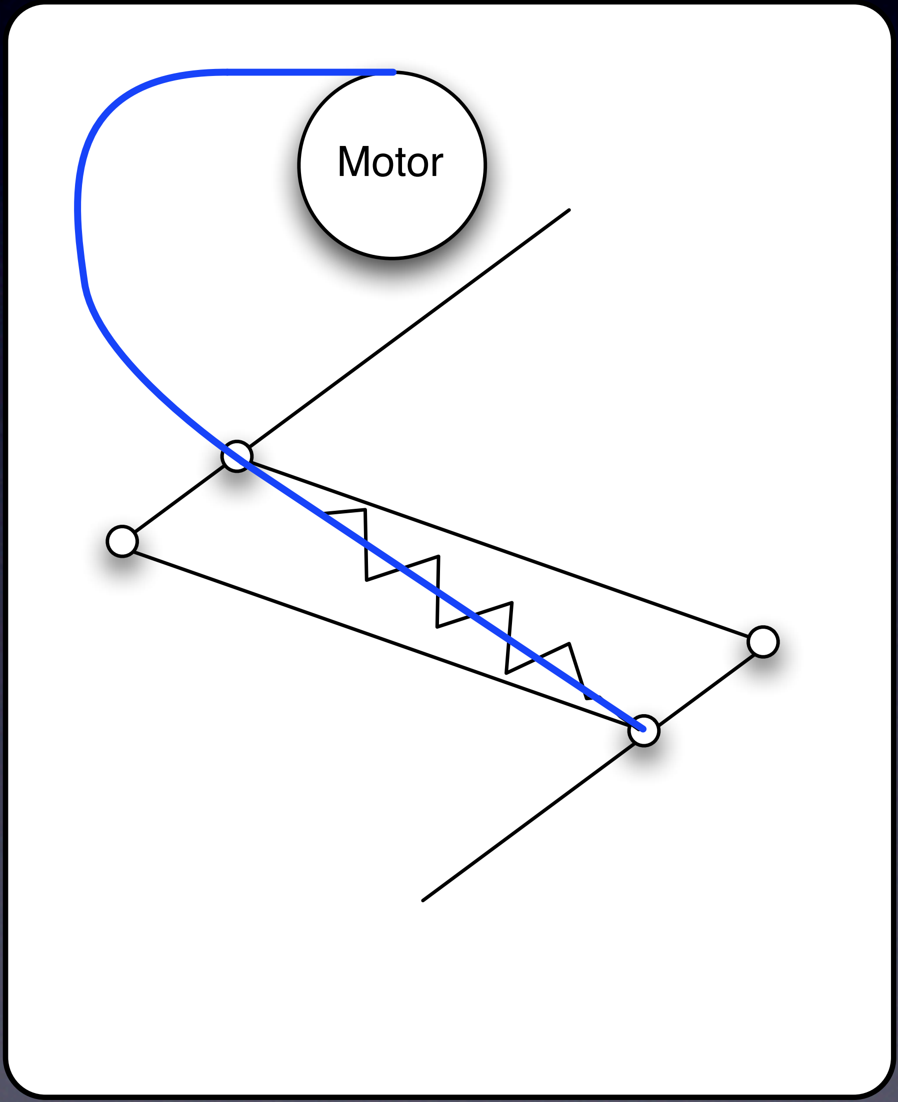
Model Update		Design of the control		Testing Mechanical Improvement		
Fix Webots Model	Prepare optimization framework	Foot trajectory definition	Gait Optimization	New Foot	New Scapula Joint	Sipnal Cord

Modelisation of the Knee Actuator



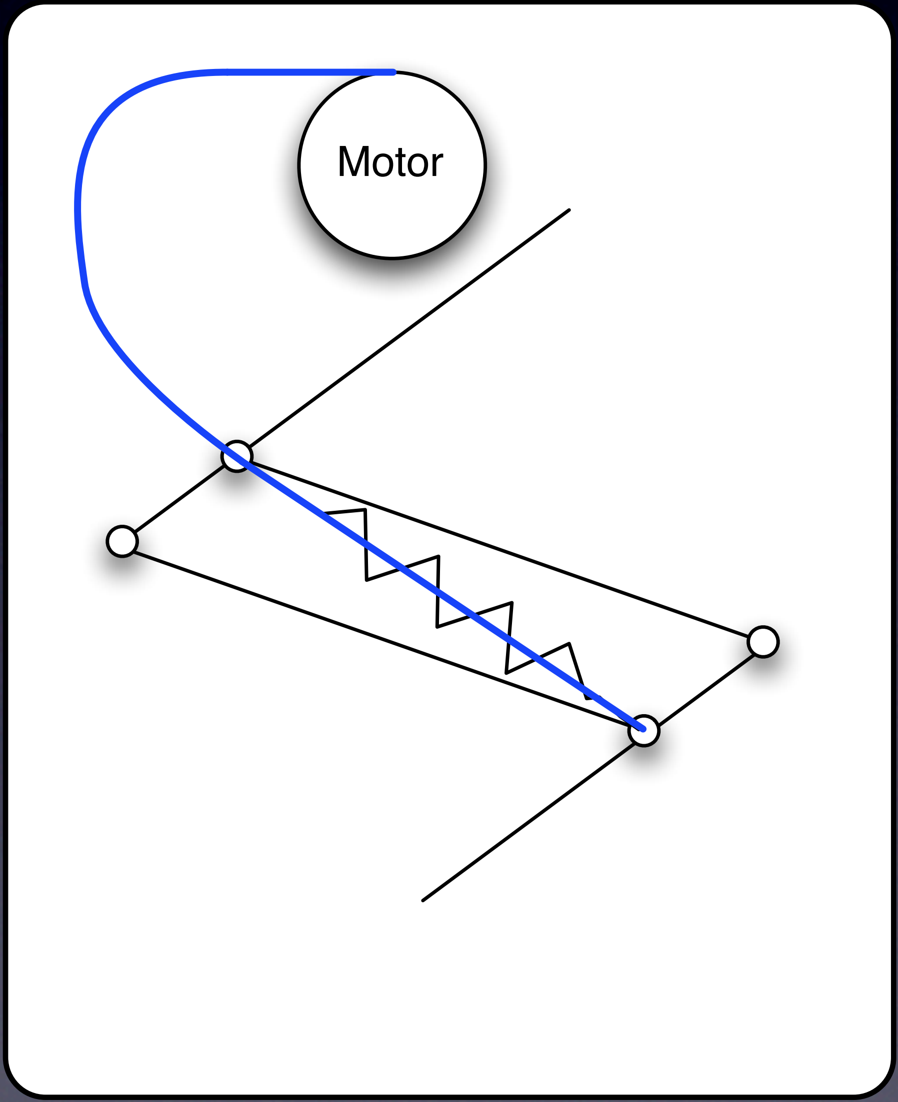
Modelisation of the Knee Actuator

- Assymetrical mechanism



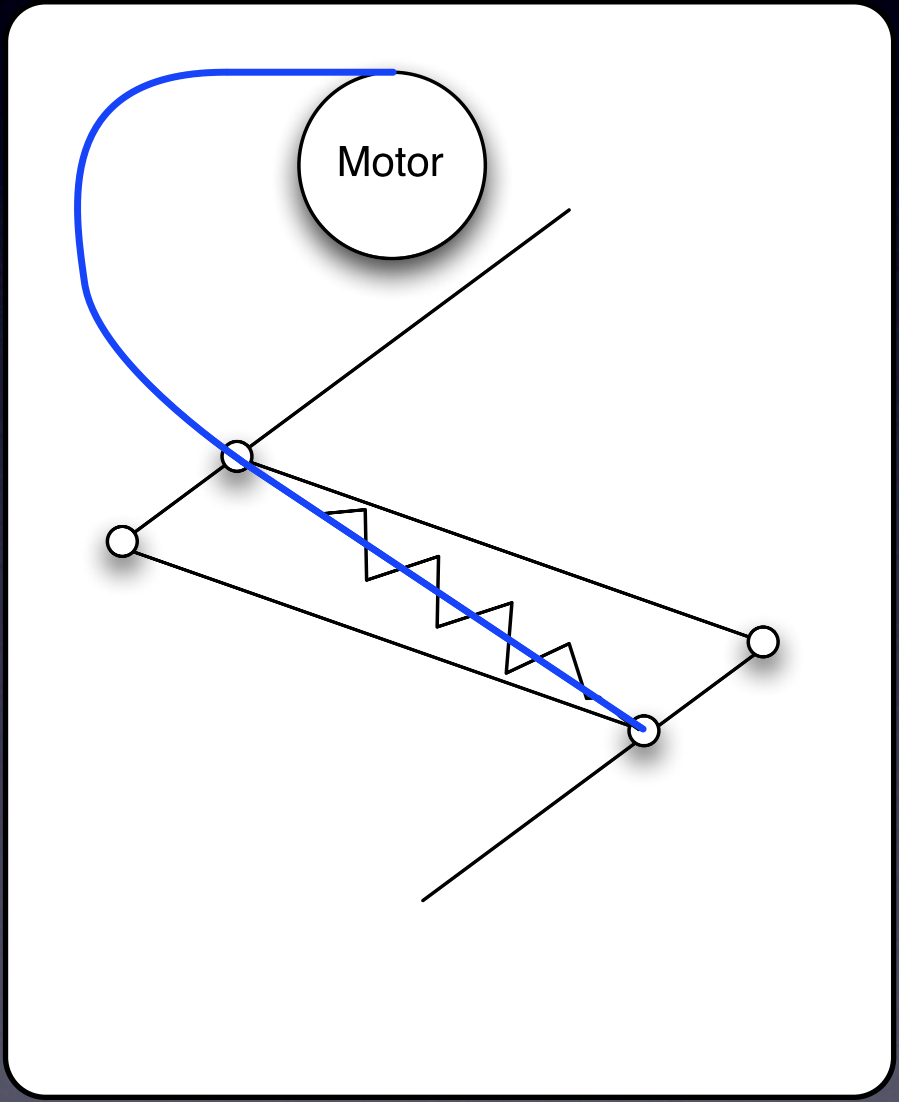
Modelisation of the Knee Actuator

- Assymetrical mechanism
- Implementation cannot be easily done with Webots Servo Node

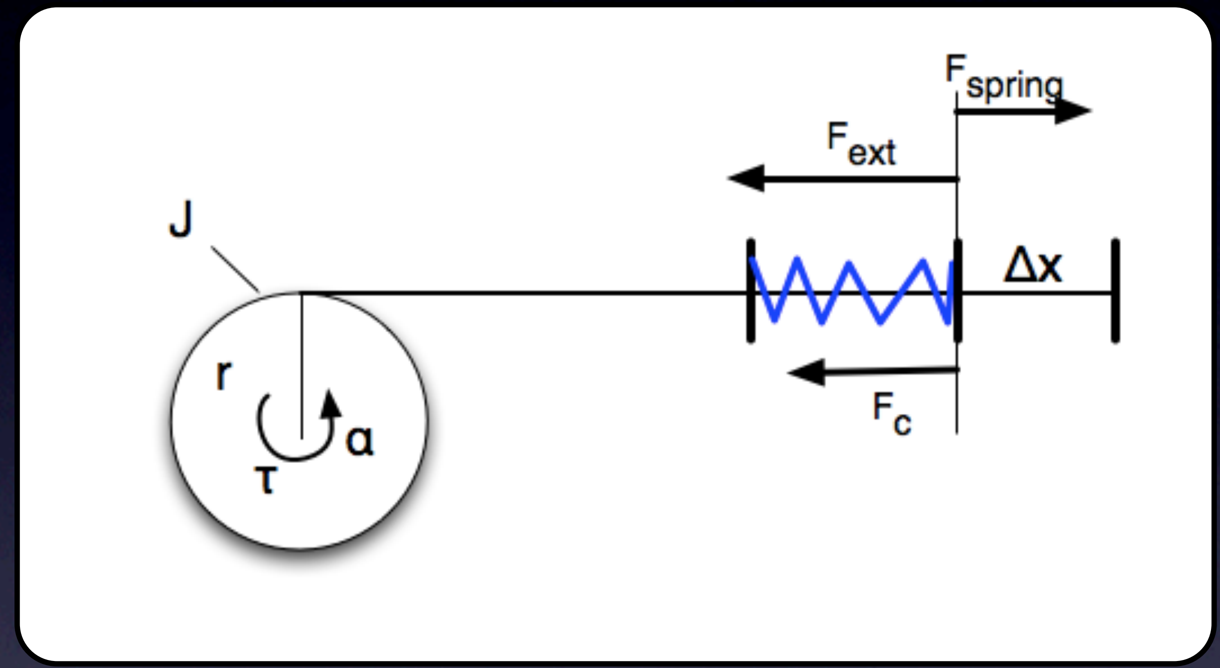


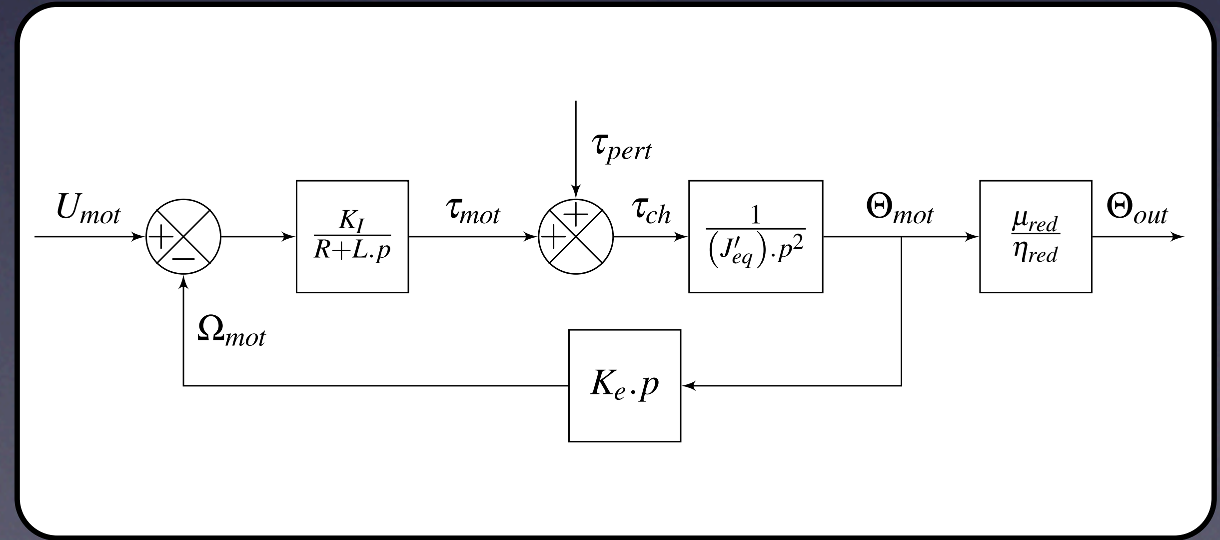
Modelisation of the Knee Actuator

- Assymetrical mechanism
- Implementation cannot be easily done with Webots Servo Node
- Make a complete Model of the Mechanism (with different state for the motor and the limb)



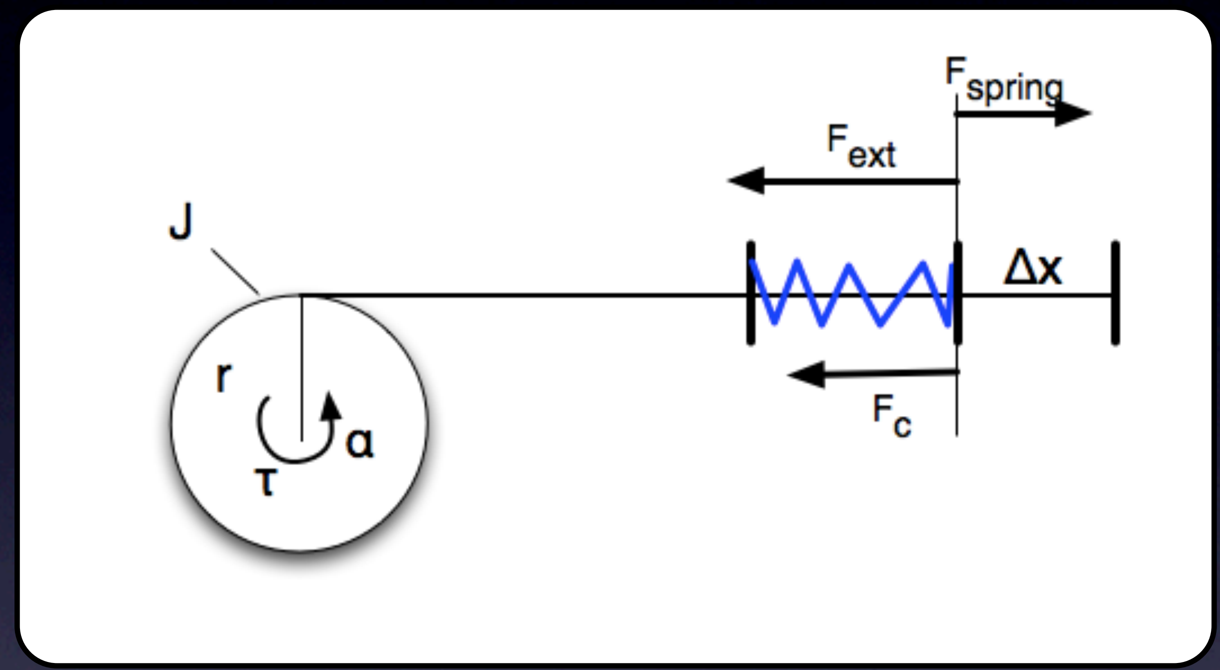
Modelisation of the Knee

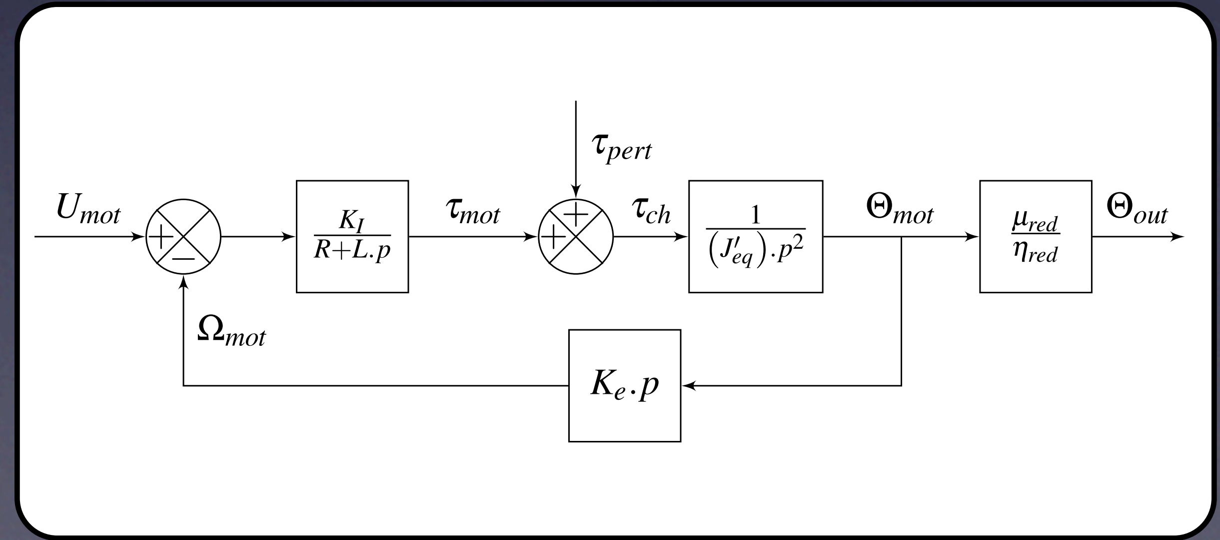




Modelisation of the Knee

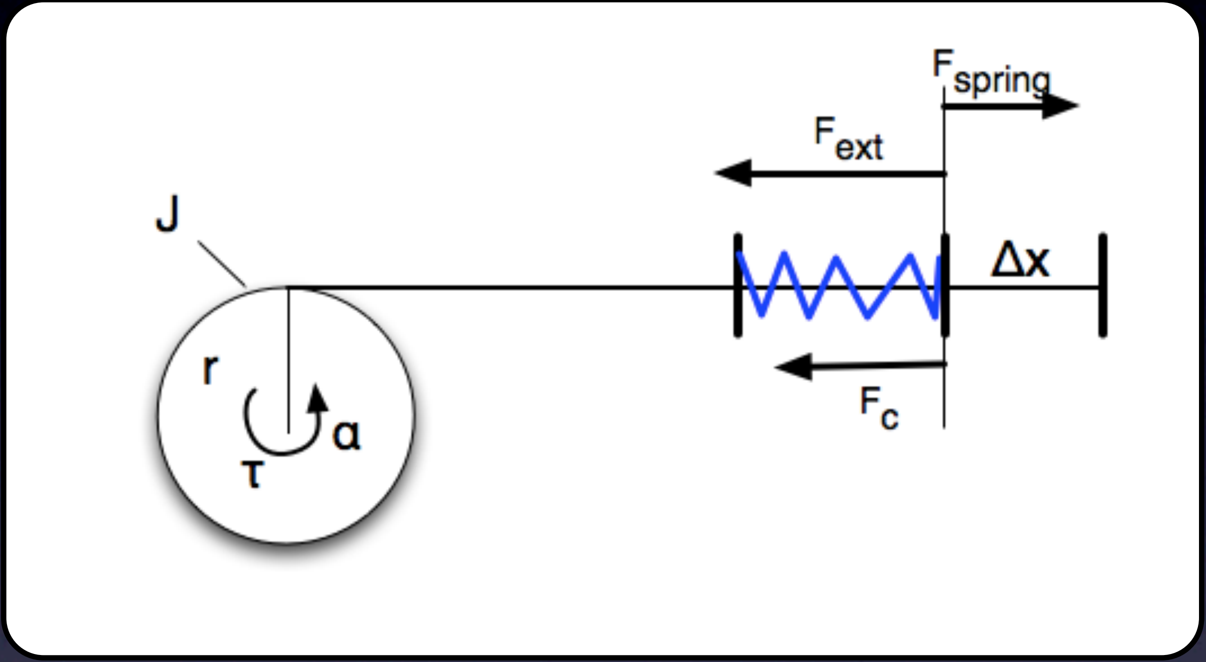
- 1) Get the value Δx^t from webots

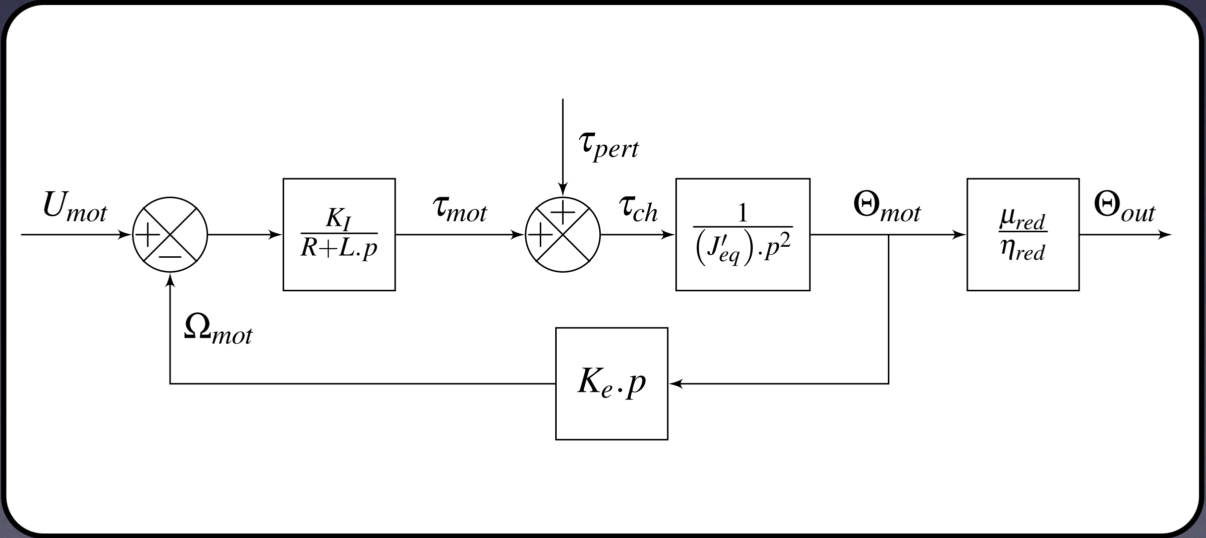




Modelisation of the Knee

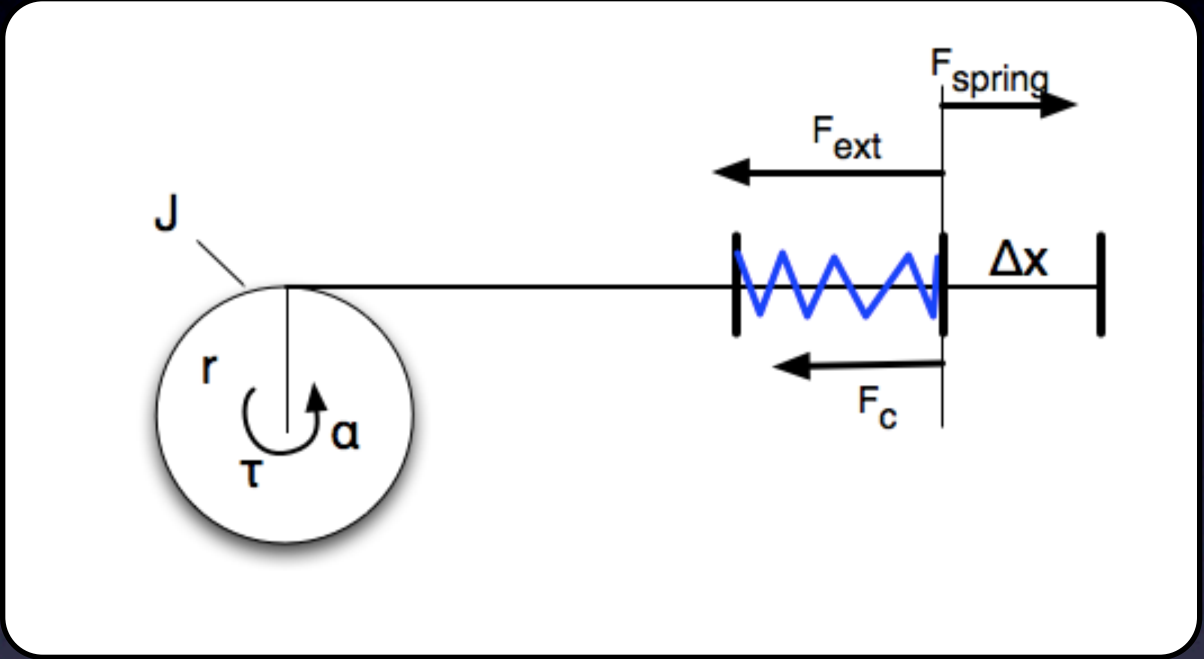
- 1) Get the value Δx^t from webots
- 2) Compute the cable tension, using a rigid or spring cable F_c

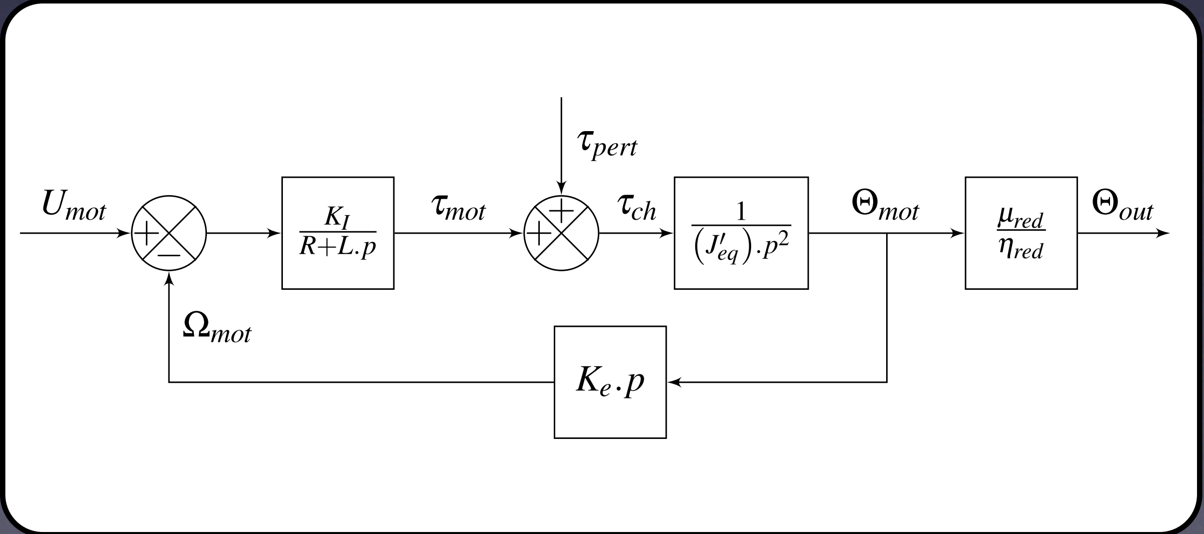




Modelisation of the Knee

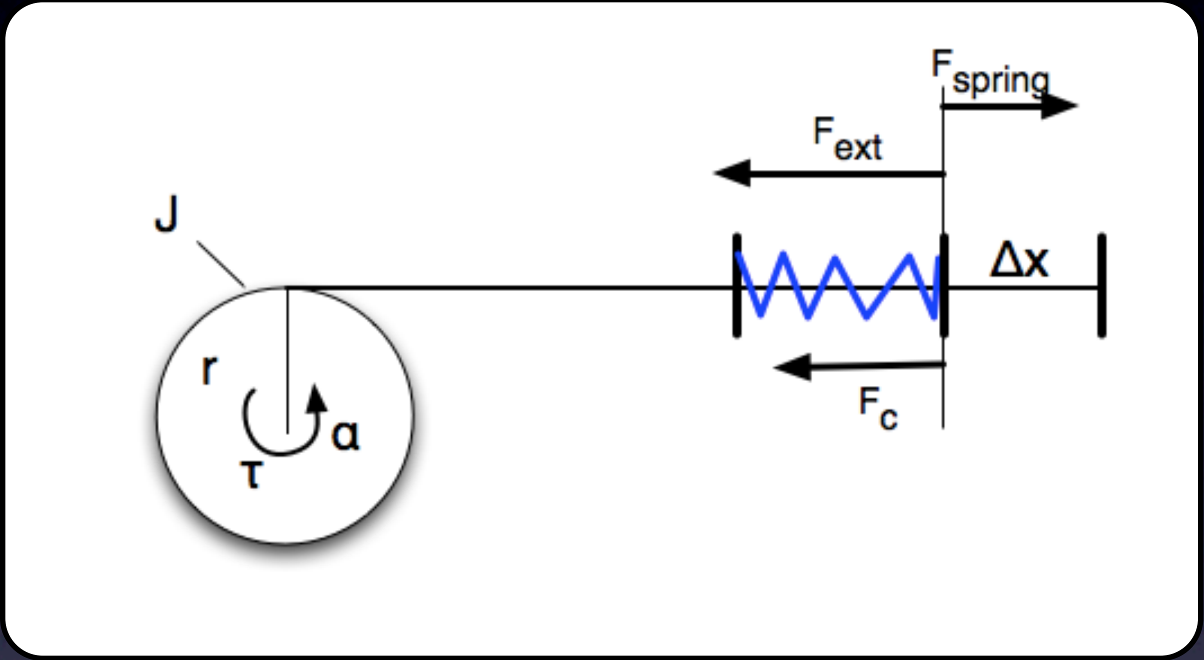
- 1) Get the value Δx^t from webots
- 2) Compute the cable tension, using a rigid or spring cable F_c
- 3) Update the value α^{t+1} knowing α^t and τ_c with the servo model.

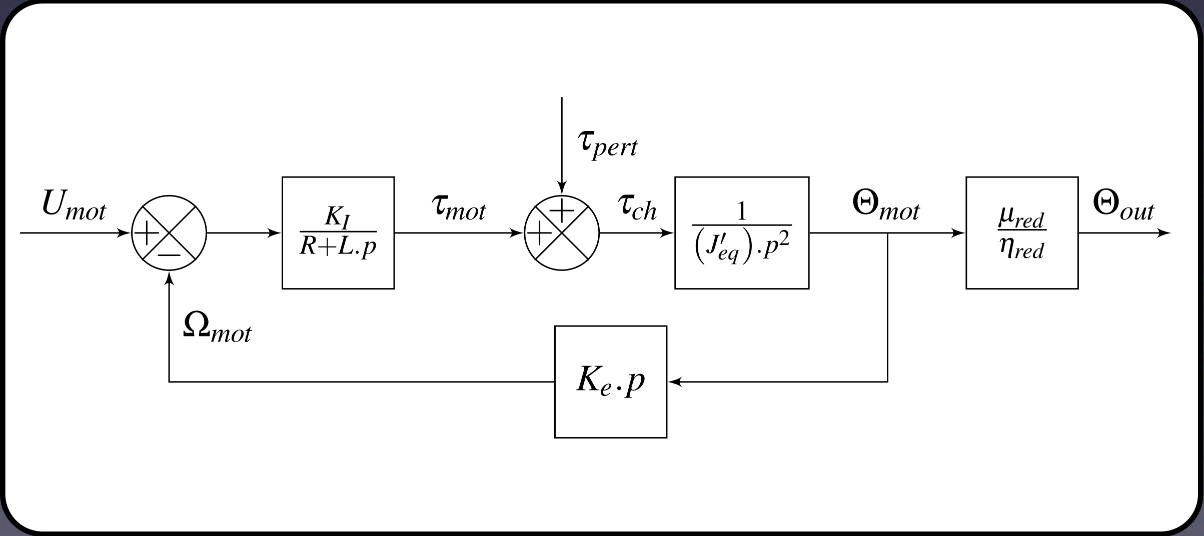




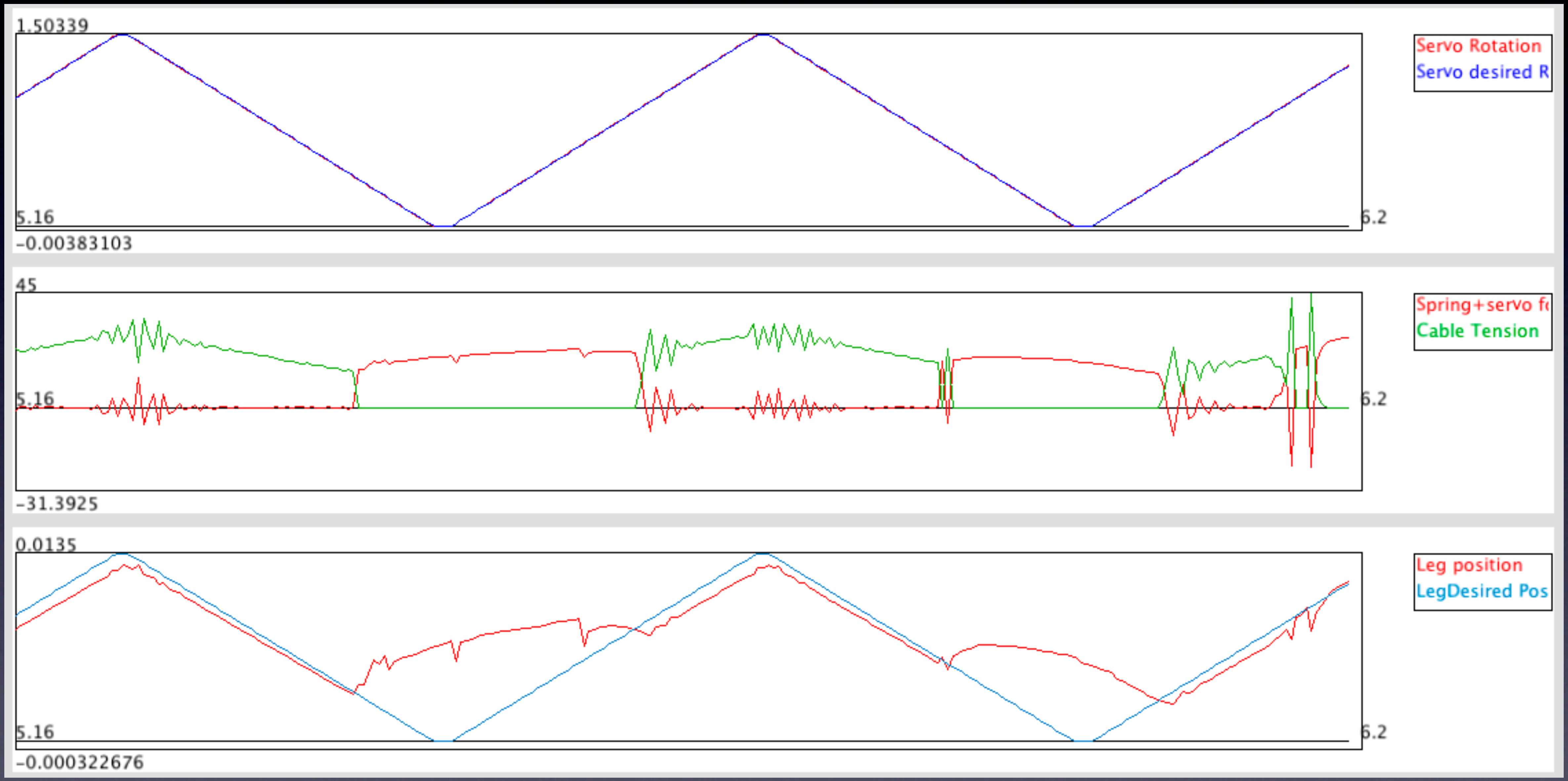
Modelisation of the Knee

- 1) Get the value Δx^t from webots
- 2) Compute the cable tension, using a rigid or spring cable F_c
- 3) Update the value α^{t+1} knowing α^t and τ_c with the servo model.
- 4) Send to Webots the value $F_c + F_{spring}$ as command



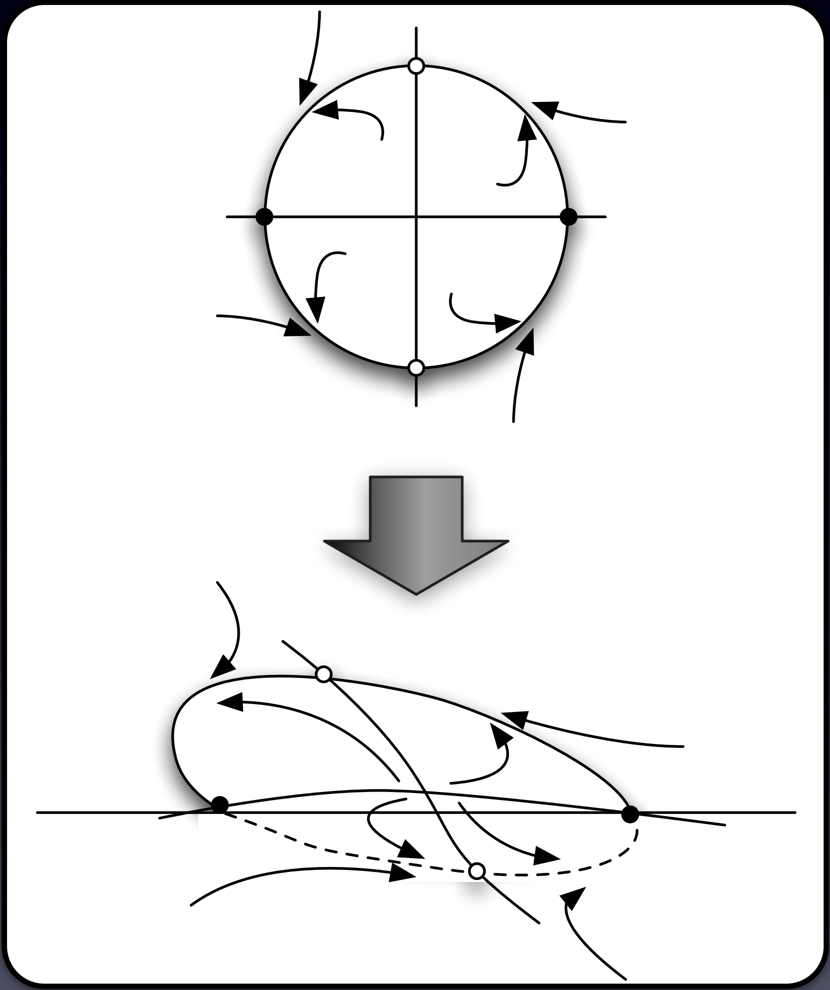


Implementation in Webots



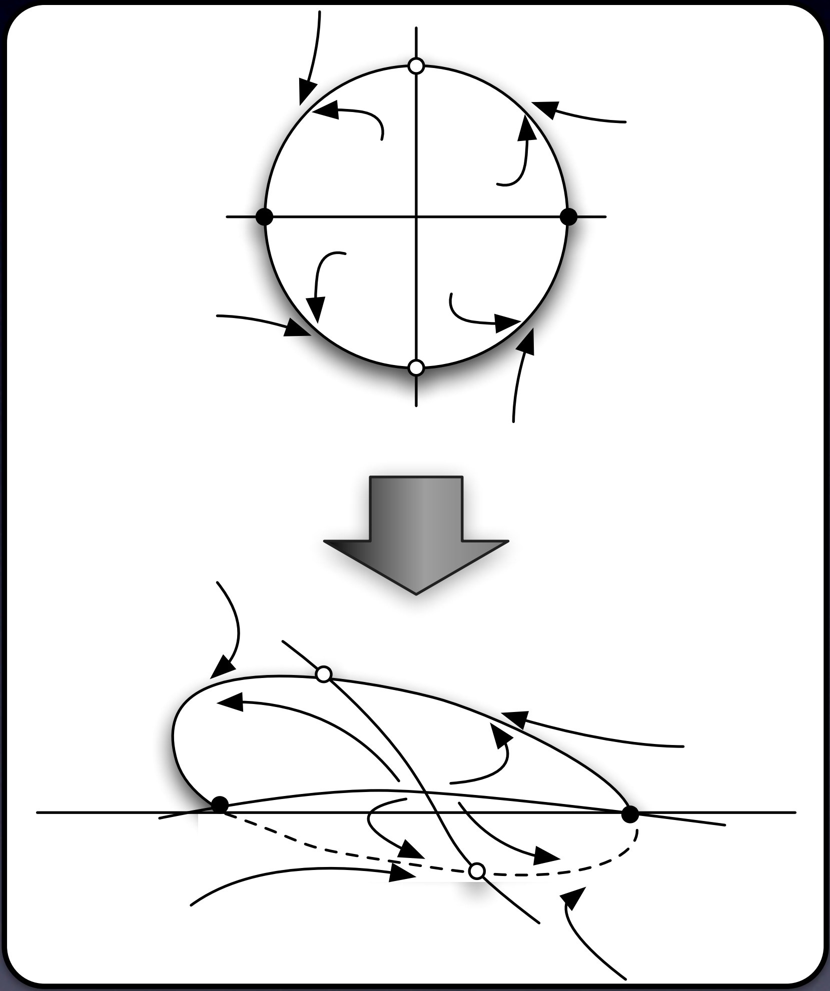
- Use a Spring and damping system (rigid cable still too unstable)
- Use Runge Kunta 4 rather than Euler method for inner state update.

Design of the CPG (not yet implemented)



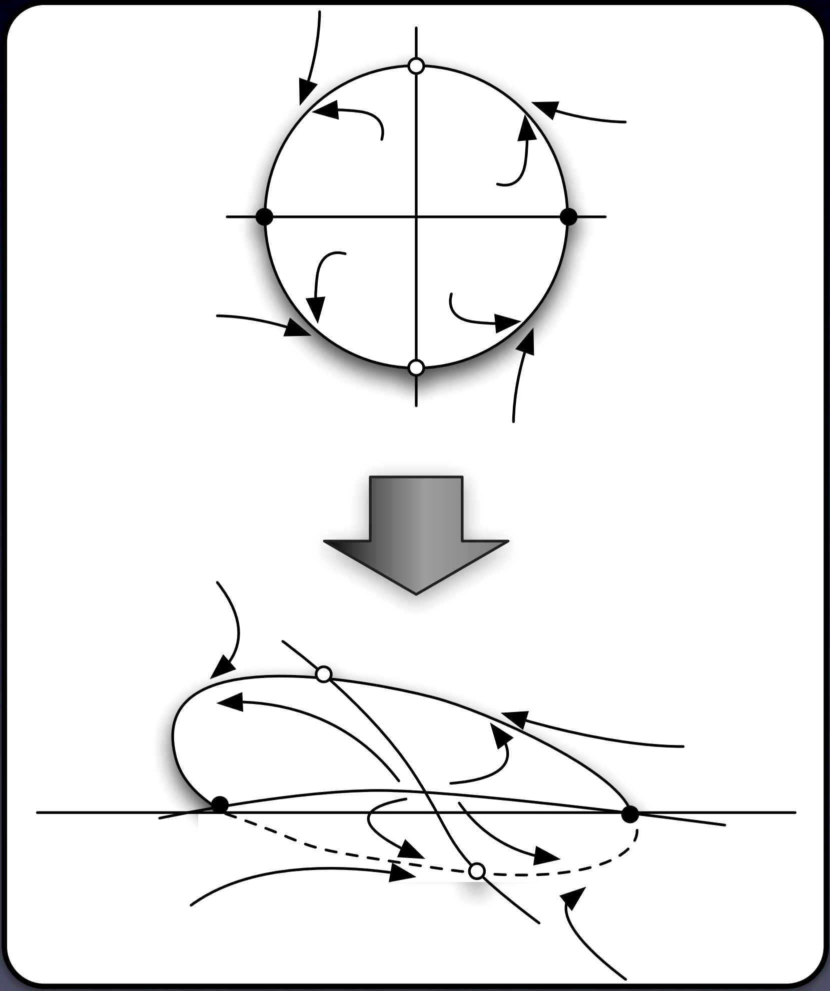
Design of the CPG (not yet implemented)

- Use the Central Pattern Generator of Ludovic Righetti.



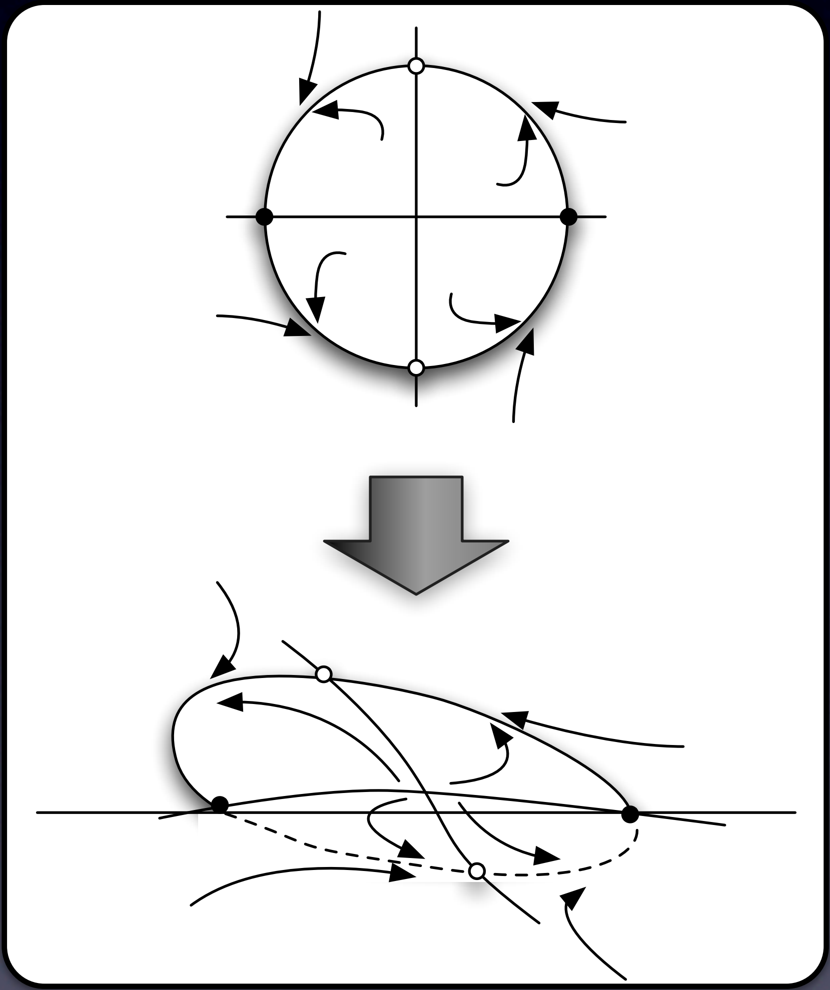
Design of the CPG (not yet implemented)

- Use the Central Pattern Generator of Ludovic Righetti.
- Transform its output to generate a foot trajectory.



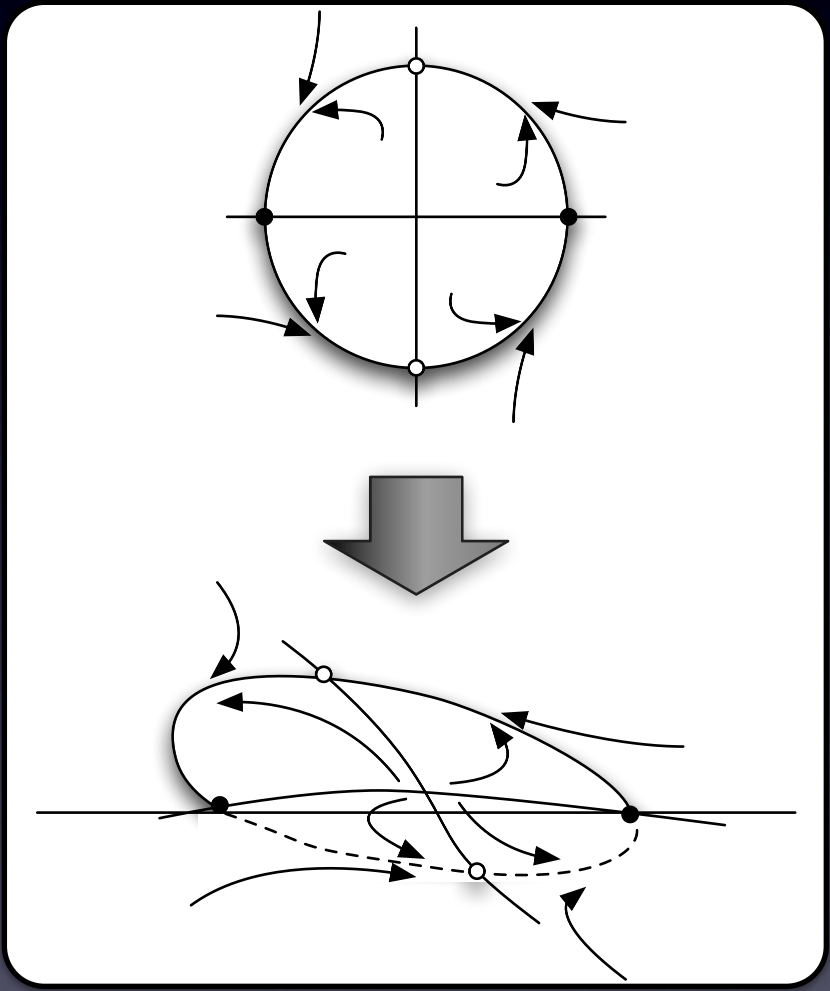
Design of the CPG (not yet implemented)

- Use the Central Pattern Generator of Ludovic Righetti.
- Transform its output to generate a foot trajectory.
  - Think rather in term of behavior, than geometry



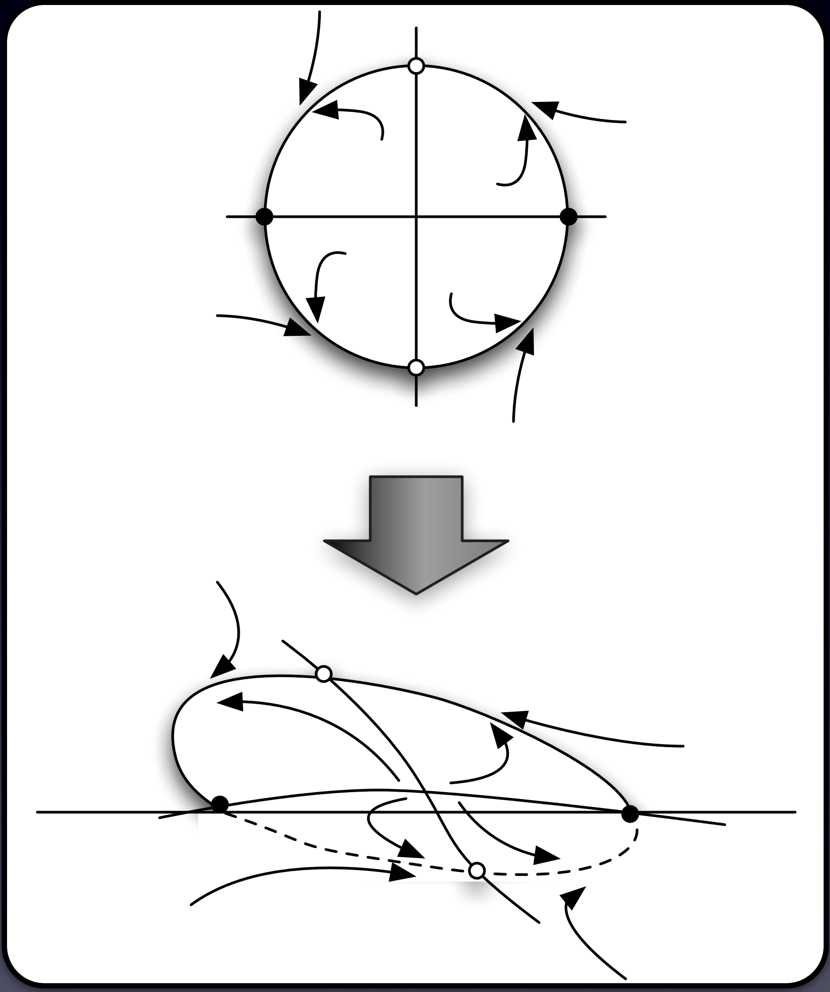
Design of the CPG (not yet implemented)

- Use the Central Pattern Generator of Ludovic Righetti.
- Transform its output to generate a foot trajectory.
  - Think rather in term of behavior, than geometry
  - Conserve the attraction property of the limit cycle.

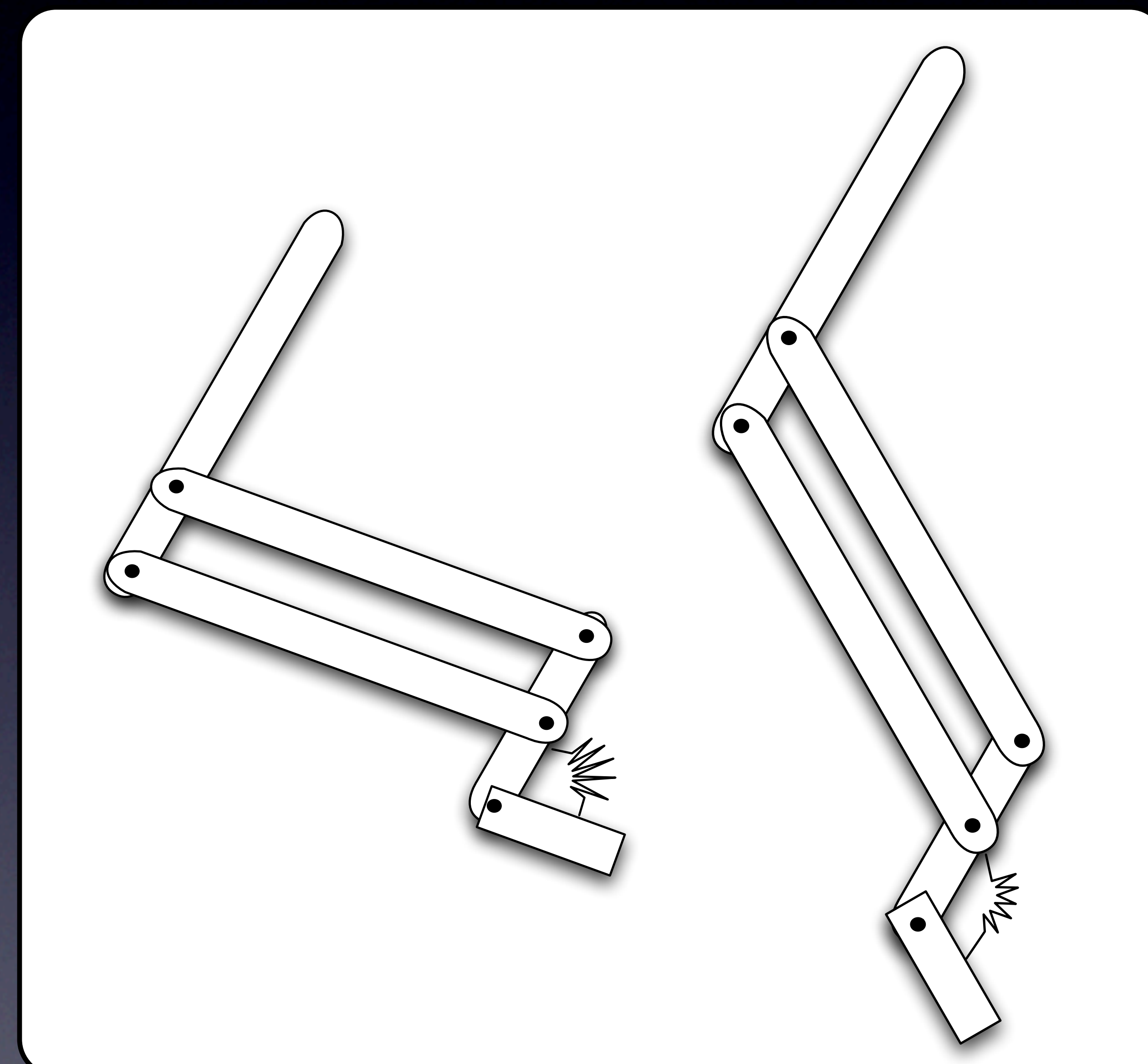


Design of the CPG (not yet implemented)

- Use the Central Pattern Generator of Ludovic Righetti.
- Transform its output to generate a foot trajectory.
  - Think rather in term of behavior, than geometry
  - Conserve the attraction property of the limit cycle.
- Use Inverse Kinematics to generate command of the Servos

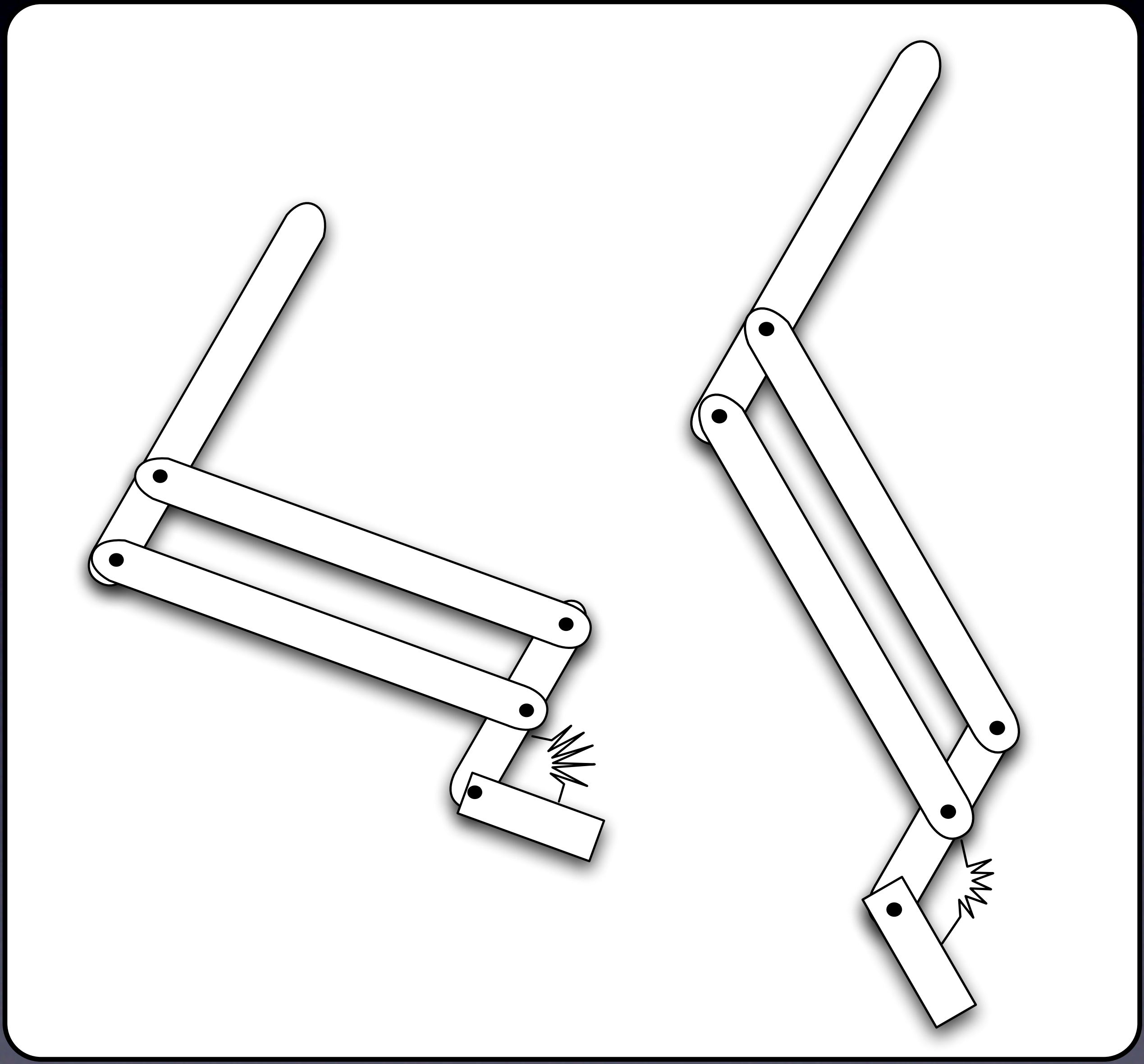


Foot improvement (not yet implemented)



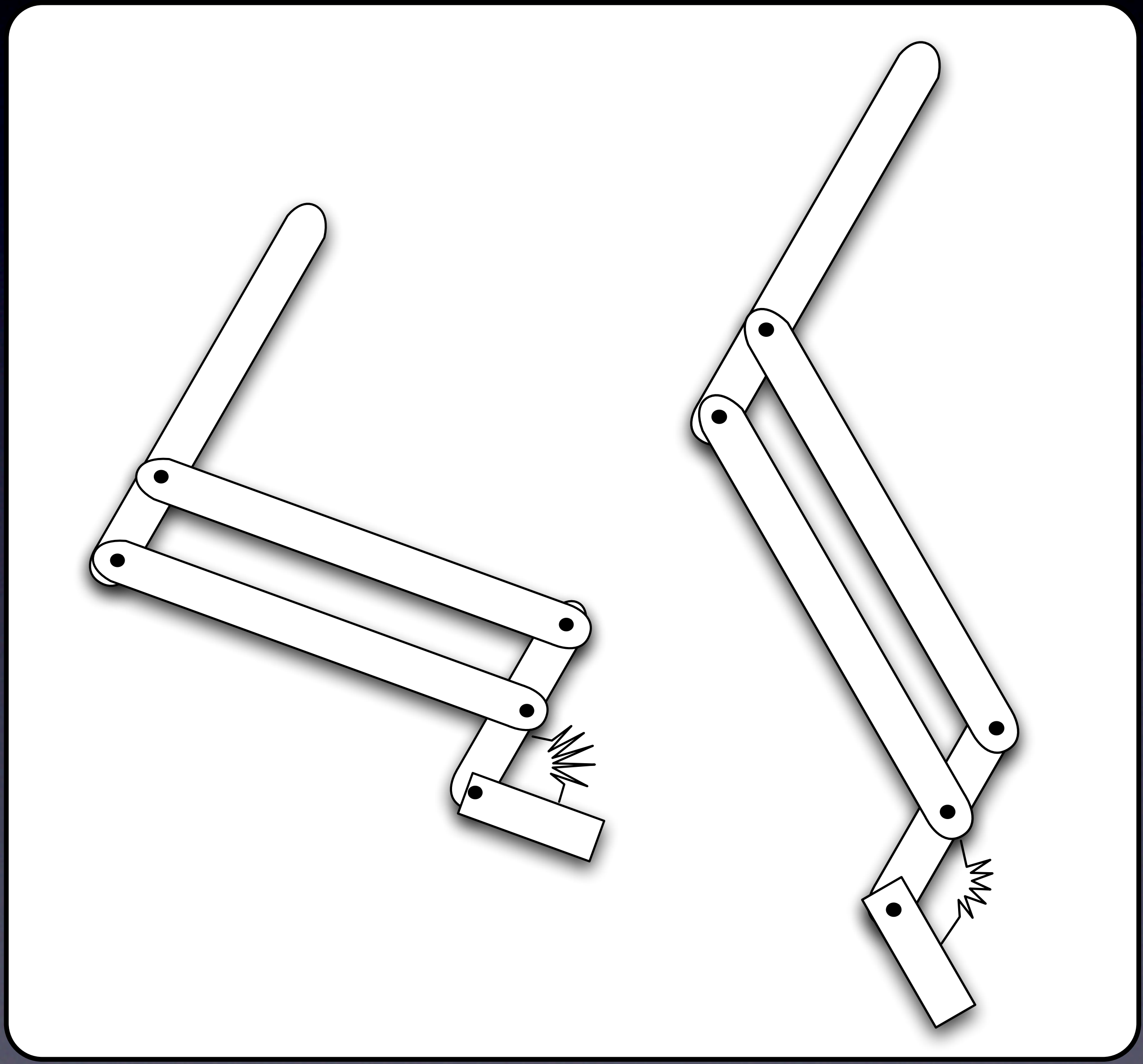
Foot improvement (not yet implemented)

- Reason : Increase foot clearence



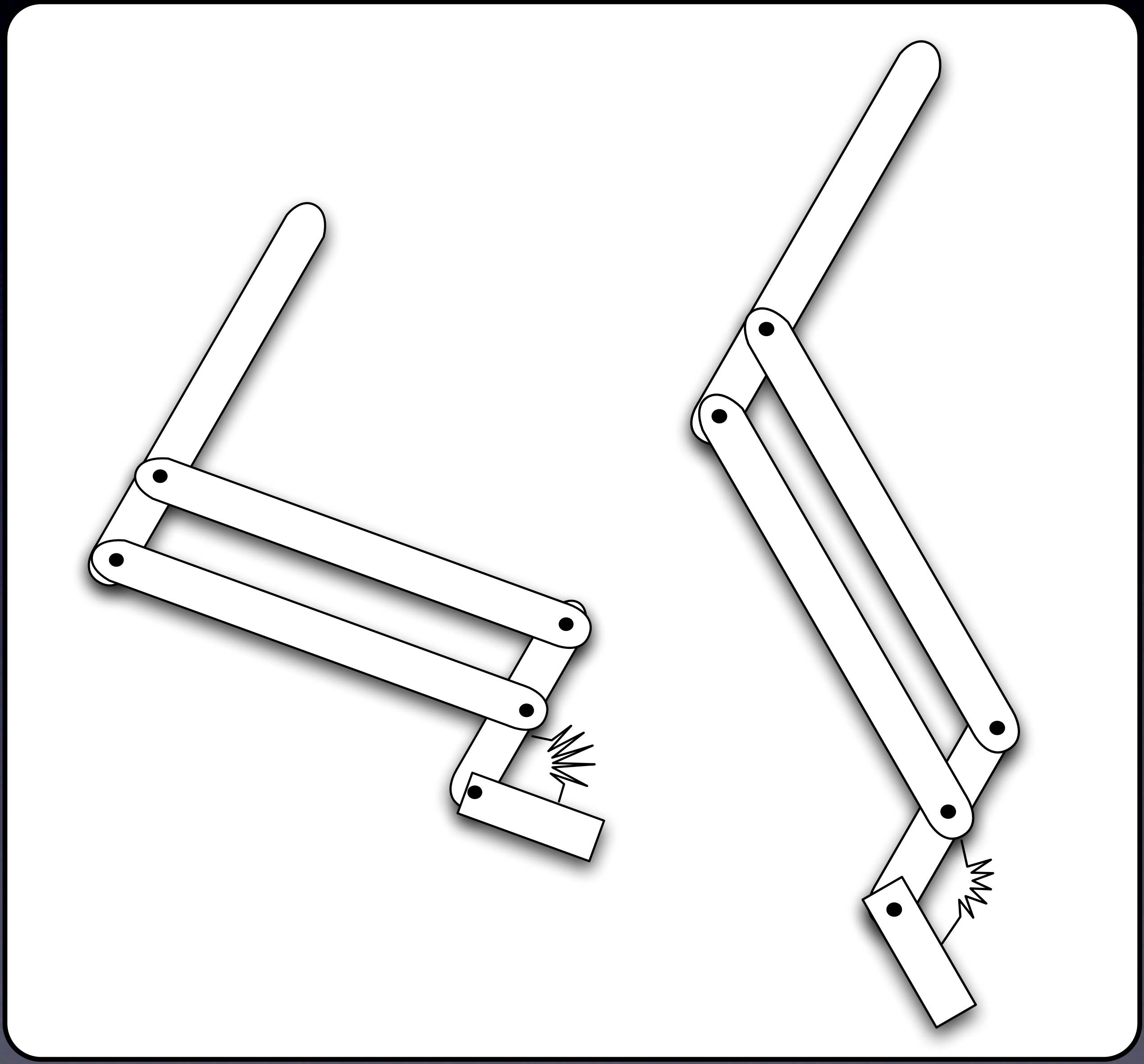
Foot improvement (not yet implemented)

- Reason : Increase foot clearence
- Additional energy storage until toe off



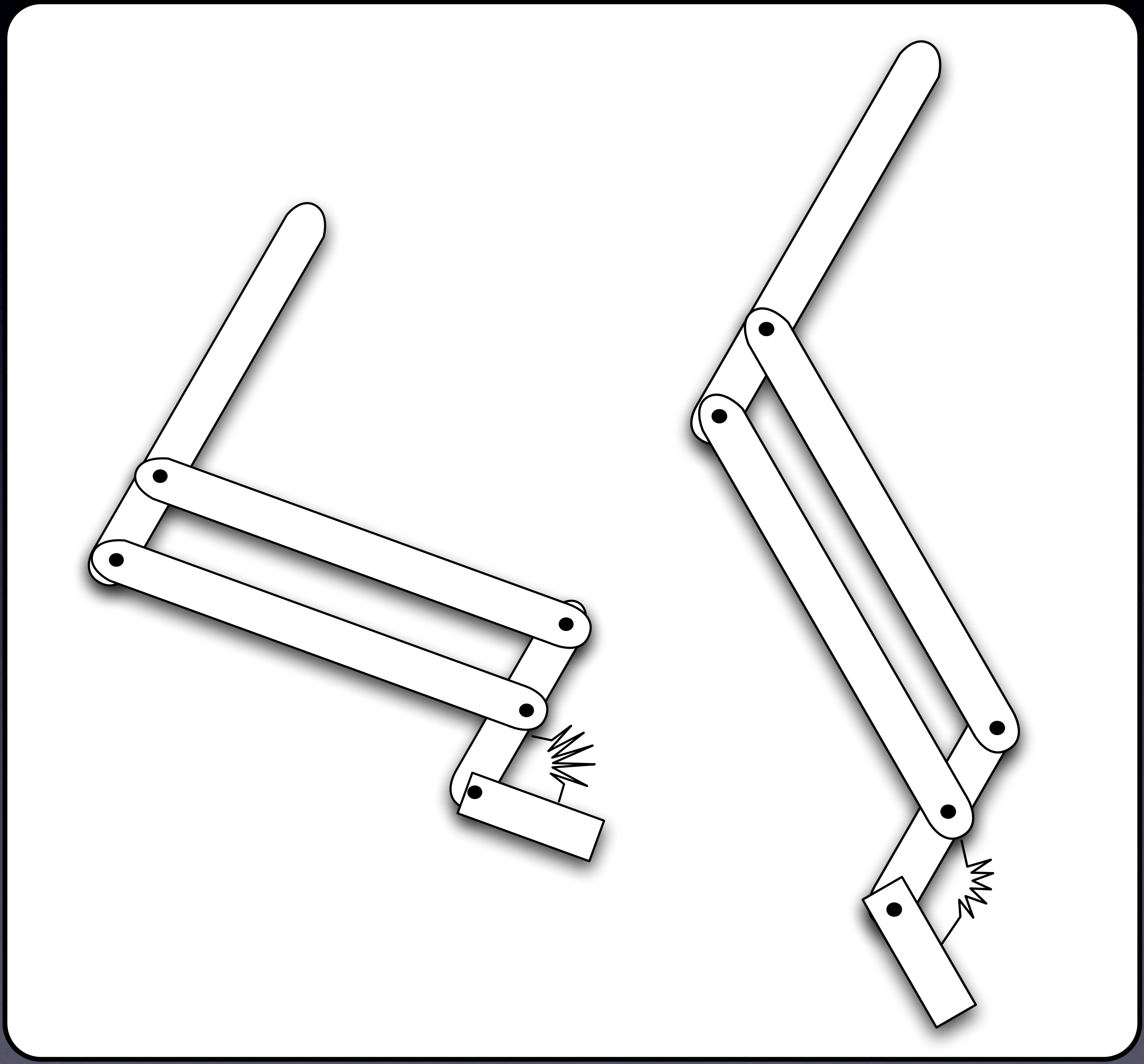
Foot improvement (not yet implemented)

- Reason : Increase foot clearence
- Additional energy storage until toe off
- Make the distal segment follow the two parralel link segment

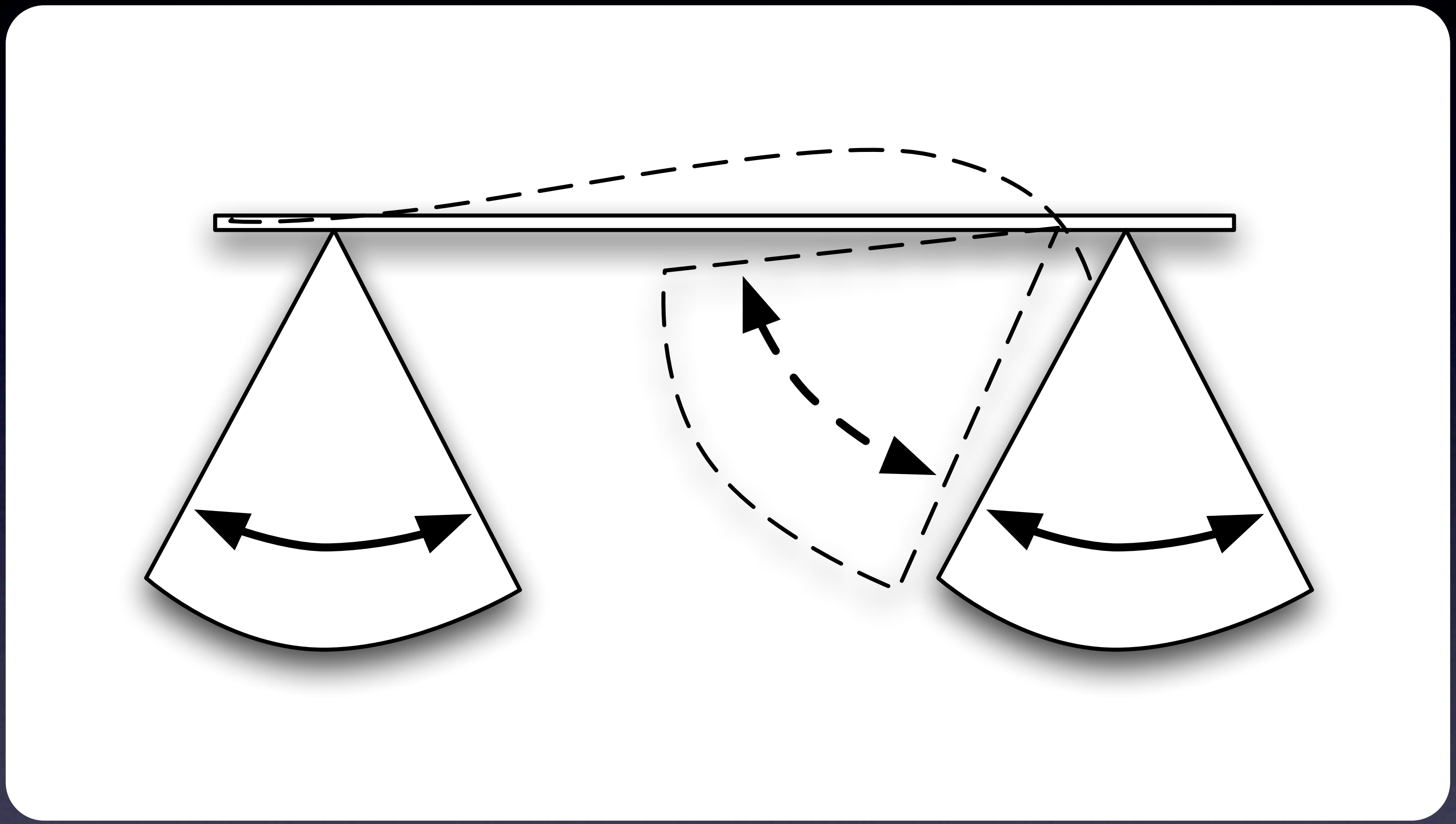


Foot improvement (not yet implemented)

- Reason : Increase foot clearence
- Additional energy storage until toe off
- Make the distal segment follow the two parralel link segment
- Use a “virtual” spring



Adding a spinal coord (not yet implemented)



- Increase further the step length for running gaits
- Spinal coord bending is equivalent of :
  - translate horizontally the Hip Joint.
  - Increase the amplitude of the Hip Joint
- Spinal coord can be reduce to a linear actuator

Questions ?