Adaptive Locomotion Controller for a Quadruped Robot

Sensory-Feedback

SEMESTER PROJECT PRESENTATION

16.01.2008

BIOLOGICALLY INSPIRED ROBOTICS GROUP (BIRG)

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- Models development
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  - Schema
- Webots implementation
  - Introduction
  - Results
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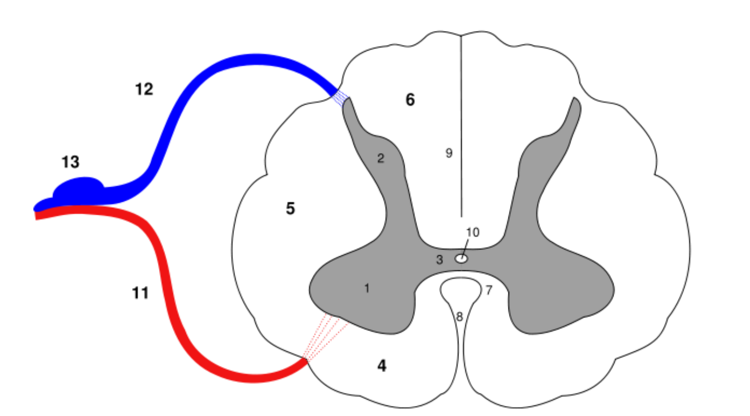
  - Introduction
  - Results
- Conclusion

Goals

- Goals of the project
  - Study the sensory feedback and some of its implementations
  - Design a model integrating feedback
  - Test and analyze this model in simulation (Webots)
  - Test the model in reality (Sony Aibo)

Theory– Biological review

- Sensory feedback
  - Important component of locomotion
  - Sensory feedback mainly required on uneven terrain
- Main pathways
  - From higher brain
  - Proprioceptive afferents
  - Cutaneous afferents



Spinal cord

Theory- Existing controllers

- Various models exist
  - For hexapod locomotion
  - For biped locomotion (walking)
  - For quadruped locomotion

- Two types of sensory feedback integration
  - Reflexes: direcly modify joint torque
  - Responses: modify the CPGs

Models development – Introduction

- Extension of the Righetti model
  - Good basis model
  - One proprioceptive feedback (stance/swing control)

- Possibilities
  - Vestibular feedback
  - Cutaneous feedback
  - Proprioception

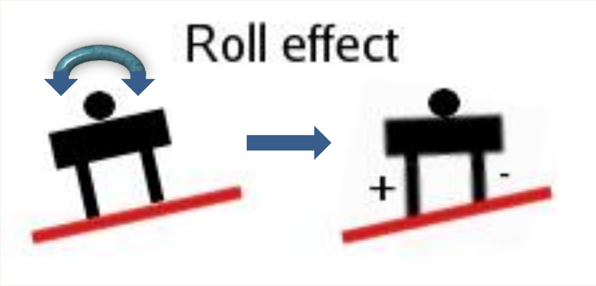
Models development – Vestibular integration

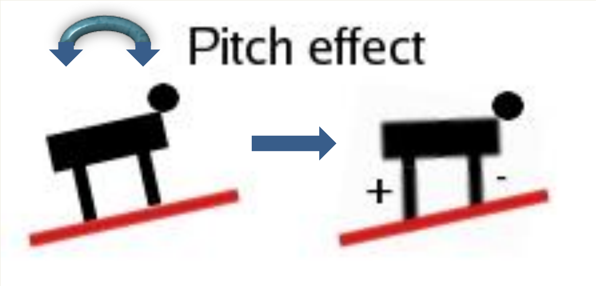
- Vestibular clues
  - Roll & pitch influence
    - Hips amplitude
    - Knees flexion
  - First model

$$\dot{x}_i = \alpha\left(\left(\mu + vest_{feed(i)}\right) - r_i^{\,2}\right)x_i - \omega y_i$$

$$\dot{y}_i = \beta\left(\left(\mu + vest_{feed(i)}\right) - r_i^{\,2}\right)y_i + \omega x_i + \sum k_{ij}\, y_j + u_i$$

$$vest_{feed(i)} = s(roll) * right(i) + s(pitch) * front(i)$$



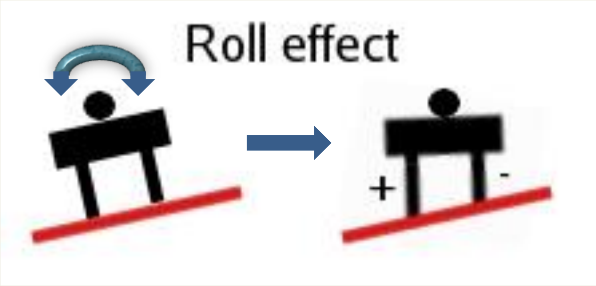


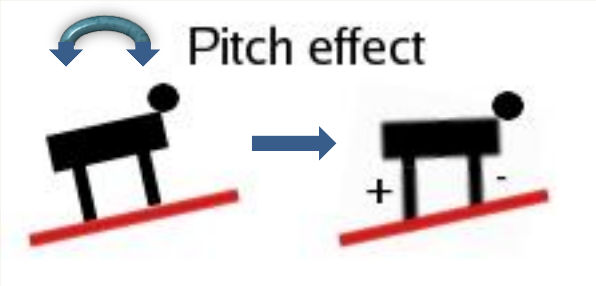
Models development – Vestibular integration

- Vestibular clues
  - Roll & pitch influence
    - Hips amplitude
    - Knees flexion
  - Second model

$$leg_i = out_{CPG(i)} * (1 + vest_{feed(i)}) * legfact(i))$$

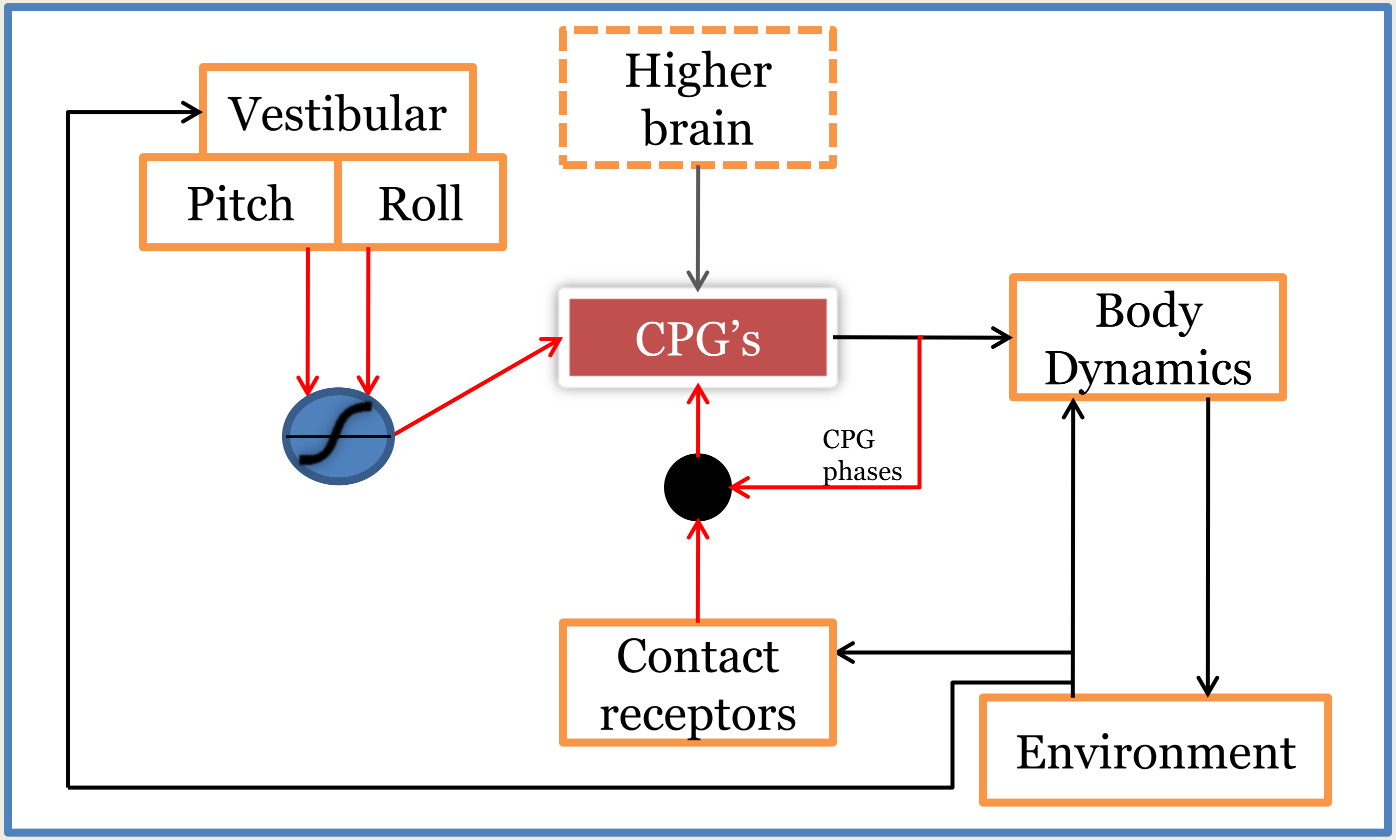
$$vest_{feed(i)} = s(roll) * right(i) + s(pitch) * front(i)$$





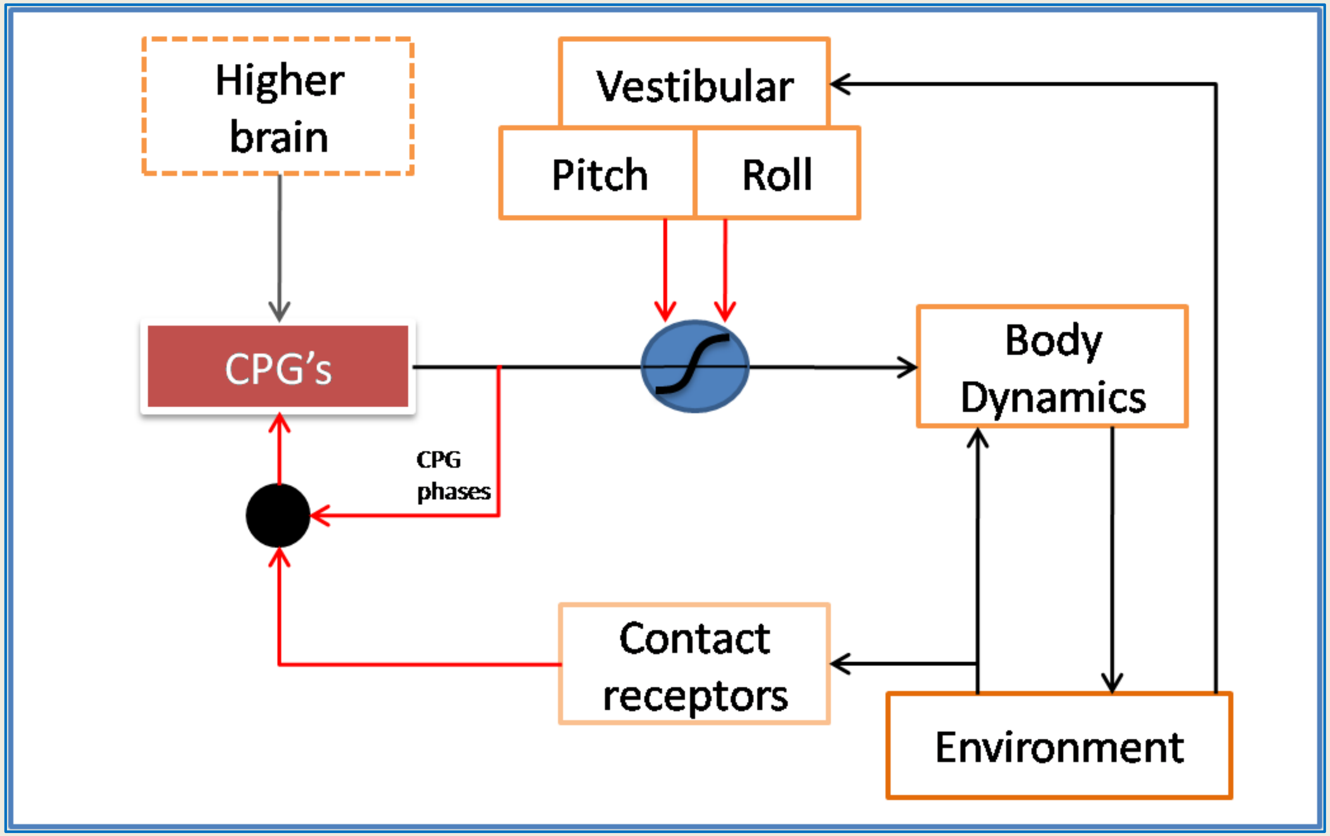
Models development – Schema

- Schema of the **vestibular response** model

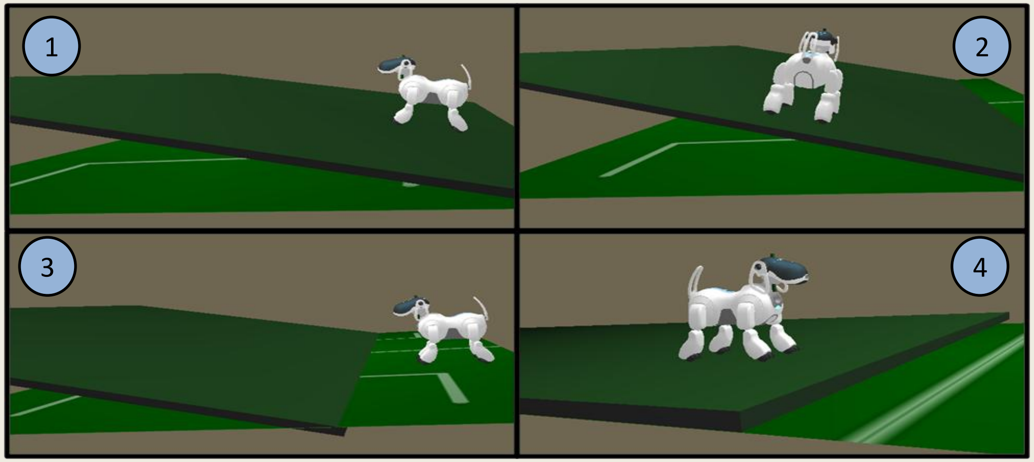


Models development – Schema

- Schema of the **vestibular reflex** model



Webots implementation – Introduction



Laterally inclined (2)			
Light	Medium	Strong	Steep
8.6°	11.5°	14.3°	17.2°

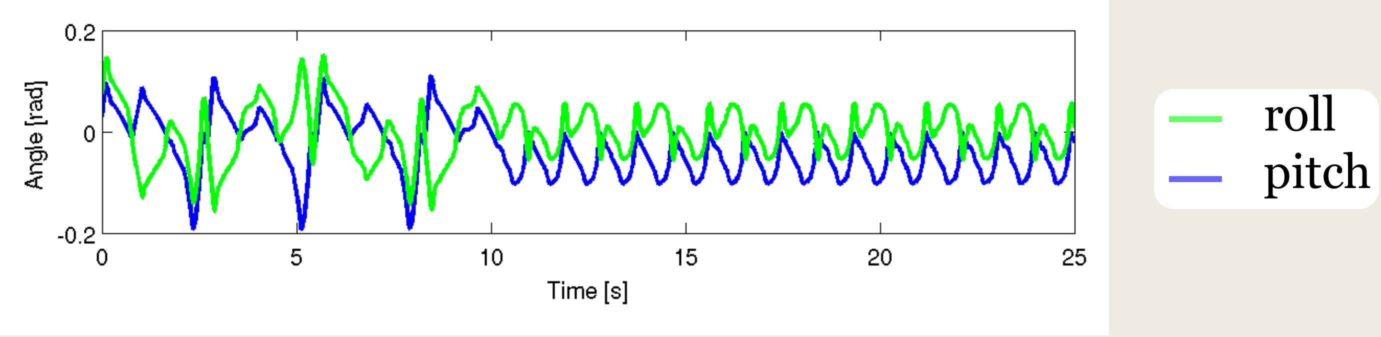
Frontally inclined (1 & 3)			
Light	Medium	Strong	Steep
5.8°	8.6°	11.5°	14.3°

Inclination of the slopes in degrees

- Wide Stability Margin (WSM)
  - Measure to quantify the stability of the robot

Webots implementation – Results

- Results Flat ground

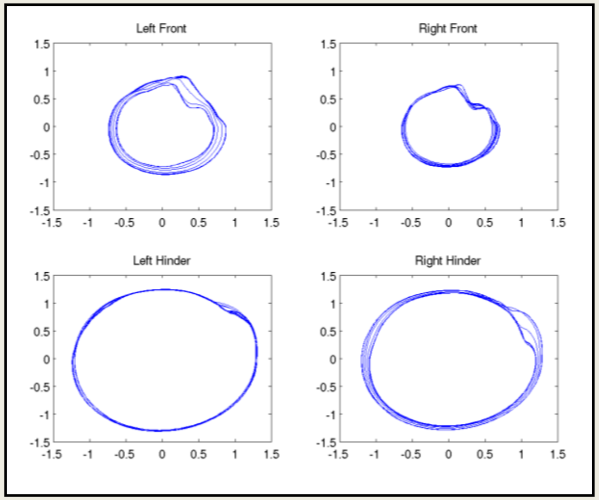


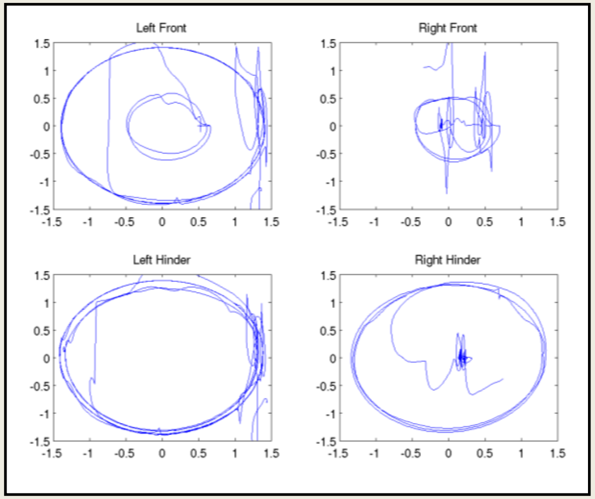
Feedback enabled after 10 sec.

Mode	WSM average
No feedback	45.891
Righetti feedback	51.003
Vestibular reflex	49.312
Vestibular response	49.072
Vest. reflex – Righetti	49.603
Vest. resp. – Righetti	52.612

Webots implementation – Results

- Vestibular response problems
  - Uncoupling of the CPGs with a **strong feedback**
  - Losing the walking pattern





Webots implementation – Results

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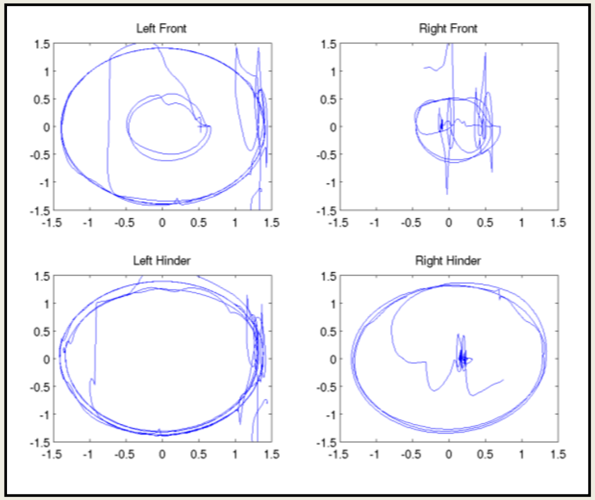
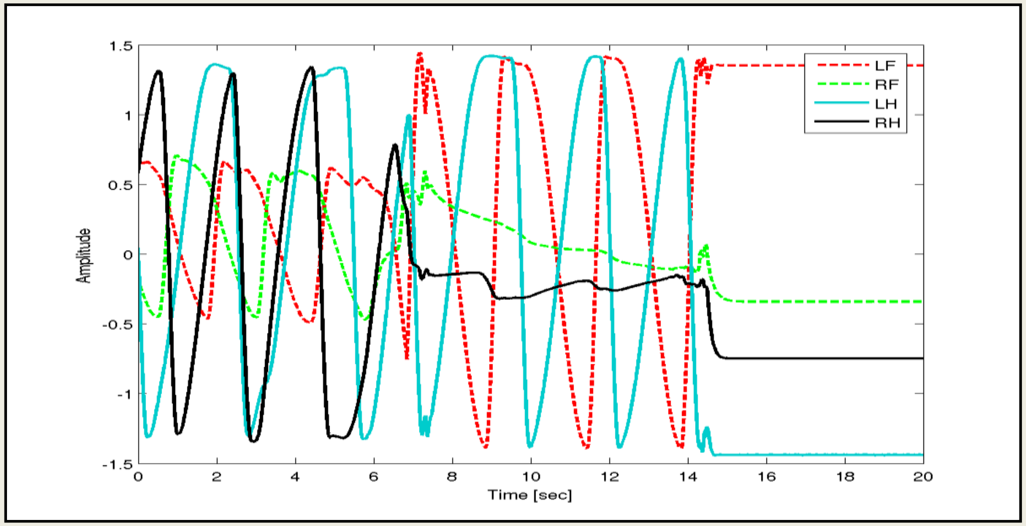
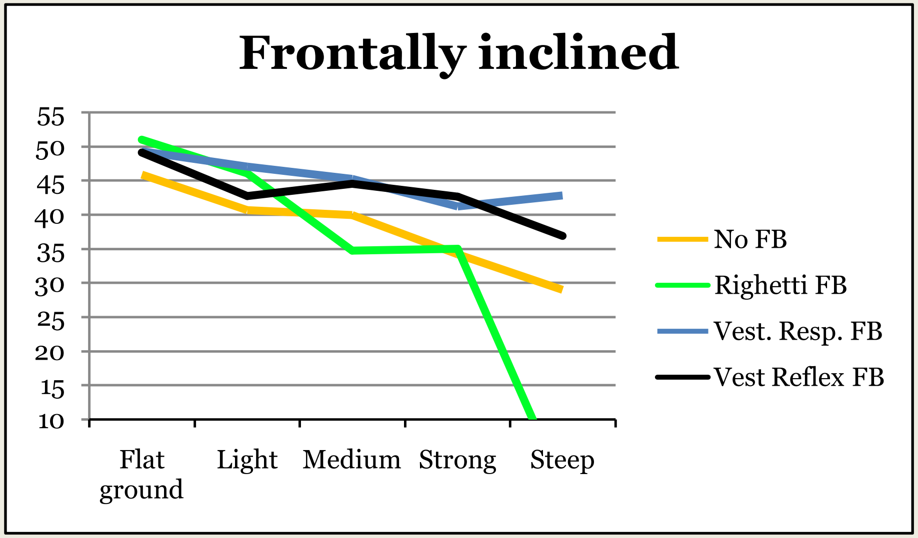
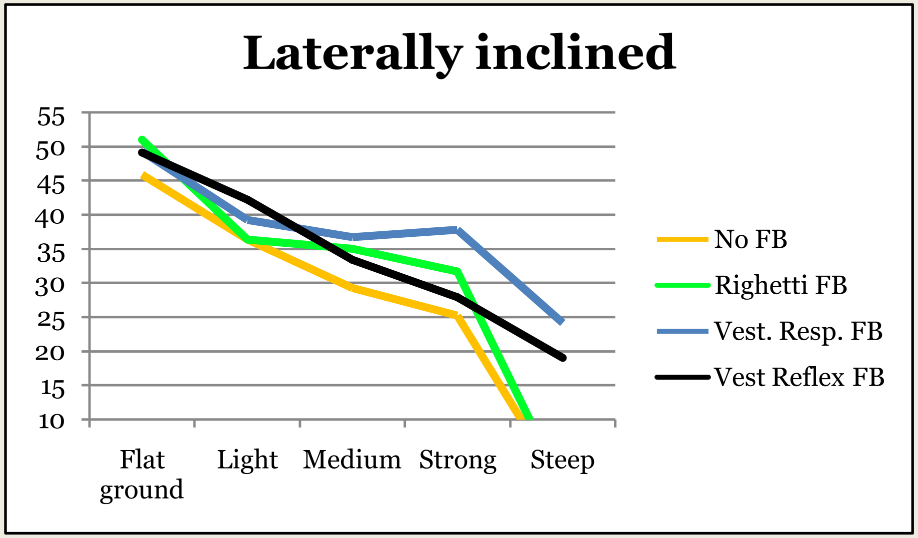




Webots implementation – Results

- Frontally and laterally inclined slopes





Webots implementation – Frontal slope

Webots implementation– Lateral slope

Real Aibo – Introduction

- Hard to obtain a good walk
  - Different values than in simulation
    - Offsets
    - Legs amplitude
    - Knees flexion
  - Different vestibular clues
    - Accelerometer values

Real Aibo – Results

Conclusion

- Vestibular feedback improves locomotion
  - Good results in simulations
    - Almost 50% better on strong slopes (WSM)
    - Walks more straight on slopes
      - Particularly the vestibular reflex model
  - Limited results in Reality
    - Walk far from perfect
    - Still improves the efficiency on slopes

Your turn !

Any questions ?