Adaptive Locomotion Controller for a Quadruped Robot Sensory-Feedback

SEMESTER PROJECT PRESENTATION
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Summary

- Goals
- Theory
  - Short sensory-feedback review
  - Existing Controllers
- Models development
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  - Vestibular integration
  - Schema
- Webots implementation
  - Introduction
  - Results
  - Videos
- Real Aibo
  - 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
  o For hexapod locomotion
  o For biped locomotion (walking)
  o For quadruped locomotion

• Two types of sensory feedback integration
  o Reflexes: directly modify joint torque
  o 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

\[
\dot{x}_i = \alpha ((\mu + vest_{feed(i)}) - r_i^2)x_i - \omega y_i
\]
\[
\dot{y}_i = \beta ((\mu + vest_{feed(i)}) - r_i^2)y_i + \omega x_i + \sum k_{ij} y_j + u_i
\]

\[vest_{feed(i)} = s(\text{roll}) \ast \text{right}(i) + s(\text{pitch}) \ast \text{front}(i)\]
Models development – Vestibular integration

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

\[ \text{leg}_i = \text{out}_{CPG(i)} \times (1 + \text{vest}_{\text{feed}(i)}) \times \text{leg}_{\text{fact}(i)} \]

\[ \text{vest}_{\text{feed}(i)} = s(\text{roll}) \times \text{right}(i) + s(\text{pitch}) \times \text{front}(i) \]
Models development – Schema

- Schema of the **vestibular response model**
Models development – Schema

- Schema of the **vestibular reflex model**

[Diagram showing the vestibular reflex model with components labeled as Higher brain, CPG’s, Vestibular, Pitch, Roll, Body Dynamics, Contact receptors, and Environment.]
Wide Stability Margin (WSM)
- Measure to quantify the stability of the robot

<table>
<thead>
<tr>
<th>Laterally inclined (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>8.6°</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Frontally inclined (1 &amp; 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
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<tr>
<td>-------</td>
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<tr>
<td>5.8°</td>
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</tbody>
</table>
Webots implementation – Results

- Results Flat ground

Feedback enabled after 10 sec.

<table>
<thead>
<tr>
<th>Mode</th>
<th>WSM average</th>
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<tbody>
<tr>
<td>No feedback</td>
<td>45.891</td>
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<tr>
<td>Righetti feedback</td>
<td>51.003</td>
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<tr>
<td>Vestibular reflex</td>
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<tr>
<td>Vestibular response</td>
<td>49.072</td>
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<tr>
<td>Vest. reflex – Righetti</td>
<td>49.603</td>
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<tr>
<td>Vest. resp. – Righetti</td>
<td>52.612</td>
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Webots implementation – Results

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

- Vestibular response problems
  - Uncoupling of the CPGs with a strong feedback
  - Losing the walking pattern
Webots implementation – Results

- Frontally and laterally inclined slopes
Webots implementation – Frontal 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?