Comparing the effects of morphological variation in locomotion using a salamander-like robot to salamanders' locomotor system

Semester Project

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Analysis of the behaviour of the salamander robot

Questions

- How does the morphology and the environment affect the gait?
- What is the optimal morphology?
- Does the robot behave similar to real salamanders?
This project is based on a previous work where the following robot configurations were analysed:

- Variable robot length
- Different number of actuators
- Reduced resolution for short robots
- Results have to be normalized
- Unknown error of the amplitude
Scheme of improvement

Additional limbs make it possible to use a new set of configurations:

Improvements

- New set of limbs
- Uniform number of robot elements
- Additional robot morphology
- Measurement of the real flexion
Gait control

controllers

- joint angle: $\alpha_i = A_i \sin(2\pi ft + \phi_i^{lag}) + \psi_i^{offset}$
- limb rotation: synchronous to the sine controller, $DF = \frac{T_{stance}}{T_{cycle}}$

Figure: Determination of the amplitude for terrestrial gaits.
Test conditions

<table>
<thead>
<tr>
<th></th>
<th>walking</th>
<th>swimming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Swimming</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
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<td>×</td>
<td>✓</td>
</tr>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Long limbs**
- ✓
- ✓

**Short limbs**
- ✓
- ×

**Frequency**
- \( f \) [Hz]
  - \( \{0.3, 0.6, 0.9\} \)
  - \( \{0.6, 0.9, 1.2\} \)

**Bending**
- \( \beta_1 \) [°]
  - \( \{40, 60, 80\} \)
  - —

**Amplitude**
- \( A \) [°]
  - —
  - \( \{10, 20, 30\} \)

**Number of waves**
- \( k \)
  - —
  - \( \{0.25, 0.5, 0.75\} \)

**Duty factor**
- —
  - \( \{50\%, 60\%, 70\%\} \)
  - —
Data processing

There’s only one experiment per parameter set.

Tracking system
- Coordinates of the LED’s
- Three independent parts are analysed

Manual tracking

The video files have been tracked manually to determine the amplitude for the terrestrial experiments.
Results: walking

**Figure:** Selected results for walking experiments for $\beta_1 = 60^\circ$. 

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Effects of morphological variation and environment
Results: swimming

Figure: Selected results for swimming experiments for $A = 20^\circ$. 
Table: Selected robot configuration for different environments.
Comparison with salamanders: indices

Body proportions

- **Hindlimb position:** \( \frac{\text{body length}}{\text{total length}} \)
- **Wolterstorff Index (WI):** \( \frac{\text{forelimb length}}{\text{interlimb distance}} \)
Salamander proportions

Exemplary species and trend

<table>
<thead>
<tr>
<th>Species</th>
<th>body/TL</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triturus dobrogicus</td>
<td>0.5</td>
<td>0.34−0.45</td>
</tr>
<tr>
<td>Triturus cristatus</td>
<td>0.5</td>
<td>0.45−0.6</td>
</tr>
<tr>
<td>Trend</td>
<td>~0.5</td>
<td>0.3−0.6</td>
</tr>
<tr>
<td>Proteus anguinus</td>
<td>0.65</td>
<td>0.11−0.16</td>
</tr>
<tr>
<td>Pleurodeles waltl</td>
<td>0.5</td>
<td>~0.4</td>
</tr>
<tr>
<td>Trend</td>
<td>~0.5</td>
<td>0.1−0.4</td>
</tr>
</tbody>
</table>
## Comparison

### Robot indices

<table>
<thead>
<tr>
<th>Robot configuration</th>
<th>body/TL</th>
<th>WI short limbs</th>
<th>WI long limbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Robot configuration 1]</td>
<td>0.7</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>![Robot configuration 2]</td>
<td>0.6</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>![Robot configuration 3]</td>
<td><strong>0.5</strong></td>
<td><strong>0.14</strong></td>
<td><strong>0.23</strong></td>
</tr>
<tr>
<td>![Robot configuration 4]</td>
<td>0.4</td>
<td>0.21</td>
<td>0.35</td>
</tr>
</tbody>
</table>

### Salamander indices

<table>
<thead>
<tr>
<th>Habitat</th>
<th>body/TL</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td>0.5</td>
<td>0.3 – 0.6</td>
</tr>
<tr>
<td>Aquatic</td>
<td>0.5</td>
<td>0.1 – 0.4</td>
</tr>
</tbody>
</table>
Thank you for your attention!