Bio-inspired Methodology for Sprawling Posture Robotic Foot Design

Semester project presentation

Laura Paez
Outline

- Motivation
- Design methodology
- Implementation
- Experimental results
- Conclusions & Questions
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Animal Aquatic Stepping

https://www.youtube.com/watch?v=lNcuZmgX5w
Pleurobot Aquatic Stepping

Aquatic stepping
Fingers and the whole foot structure are important for walking gaits in sprawling posture robots, especially for aquatic stepping gaits, as some recent experiments using Pleurobot indicate a thrust generation due to the finger push off the ground.
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• Motivation
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Systematic selection of representative species (Sprawling posture, undulatory spine)
Clustering of species by biomechanic evaluation

<table>
<thead>
<tr>
<th></th>
<th>A. mississippiensis</th>
<th>O. tetraspis</th>
<th>U. scoparia</th>
<th>P. platyrhinos</th>
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<td>Speed (m/s)</td>
<td>6.667</td>
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<td>Mass (g)</td>
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<td>(18-32)x10³</td>
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<td>[9] [10]</td>
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Table 2.1: Parameters of selected species
Clustering of species by biomechanic evaluation
Clustering of species by biomechanic evaluation

The robot designers have already a robot (e.g. Pleurobot)
Foot design parameters

(a) Foot design parameters

(b) Foot design parameters

(c) Foot design parameters

- Tarsus Width
- Tarsus Length
- Finger Length
- Finger Width
# Foot design parameters

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<tr>
<th>Animal</th>
<th>Family</th>
<th>ForeLimb</th>
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<td>Tarsus Length</td>
<td>Finger Length</td>
<td>Finger Width</td>
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<td>Lizard</td>
<td>Phrynosomatidae</td>
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<td>5.14</td>
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</table>
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Animal species and features design selection

Tiger salamander
(*Ambystoma tigrinum*)

- Bone structure and bone dimensions
- Data related to the kinematics of the stride
- Measurements of ground reaction forces (GRF)
Technology Selection

Hillberry Joint

- Pair of cylinders in rolling contact on each other
- Low friction
- Elastic ligaments

Pisa/IIT SoftHand
Finger design

(a) Angle on last phalange and metatarsus
(b) Applying force to (a)

(c) Angle on last phalanx
(d) Applying force to (c)

(e) Angle on metatarsus
(f) Applying force to (e)

Figure 3.2: Testing angle modifications effects
Mechanical integration

(a) Tibia (Motor connector)
(b) Tibia (Ankle connector)
(c) Ankle
(d) Tarsus (Palm)
(e) Metatarsus (Connection with Tarsus)
(f) Metatarsus (Connection with Phalanx)

Figure 3.3: Mechanical parts
Final Foot Design.
Figure 3.5: Foot implemented
Animal vs Robotic Foot

<table>
<thead>
<tr>
<th></th>
<th>Tarsus Width</th>
<th>Tarsus Length</th>
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<th>Finger Width</th>
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<td>Using Finger Width=10.25 (mm)</td>
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<td>48.8</td>
<td>89.6</td>
<td>10.2</td>
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<tr>
<td>Measures foot robot implementation (mm)</td>
<td>50</td>
<td>58</td>
<td>100</td>
<td>10.2</td>
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<tr>
<td>Error (absolute and [%])</td>
<td>0.2 [0.4%]</td>
<td>10.8 [18%]</td>
<td>10.4 [10%]</td>
<td>0 [0%]</td>
</tr>
</tbody>
</table>

Table 3.1: Comparison measures
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Set up
Experiment
Figure 4.3: Comparisons between robot and animal GRF. (a) Average GRF results for one stride measured from experiments. Upper speed (red) and Lower speed (blue). (b) Animal data [34].
Kinematic data synchronization: MoCap and Force Plates
Final Sequence
Figure 4.6: Left, two fingers on a rock while the third one adapts to the floor. Right, the same experiment but using only one finger on the rock.
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Conclusion

Fingers and the whole foot structure are important for walking gaits in sprawling posture robots, especially for aquatic stepping gaits, as some recent experiments using Pleurobot indicate a thrust generation due to the finger push off the ground.

- **Experiments** carried out with the proposed foot robot mechanism were sufficient to **describe** when and how each of the **fingers** action during the whole stride **impact on the GRFs**.

- Enough **experimental evidence** to keep working on the **hypothesis** above. Going deeper in this study using such a mechanical foot implementation.
Conclusion

The foot design, provides richer understanding of locomotion schemes by featuring robust ground placement. Making robots like Pleurobot being more accurate w.r.t. biology.

A great consequence of the technology used for the implementation is the terrain adaptability and simultaneous high resilience to hit obstacles while in operation.

This provides a high potential in the use of such mechanisms for real field tasks in search and rescue.
Conclusion

All these **presented features** related to the final implementation of the robotic foot mechanism, came from a **systematic design methodology** which is **bio-inspired**.

Classification of morphologies and the extraction of simple parameters allow the **design** of different feet for **different sprawling animals** in a generic way.

The **top-down approach** in animal taxonomy allows the **user** of the methodology to simply **locate the biological characteristics** like sprawling posture and undulatory spine **design** its own food/robot.

Beyond this design **still remain** interesting open questions like how to program the **adequate foot actuation** according to the **motion** of the whole leg and even more, according to the **terrain**.
References


2. http://a-z-animals.com/animals/dwarf-crocodile/


References


12. http://a-z-animals.com/animals/tiger-salamander/

Questions?