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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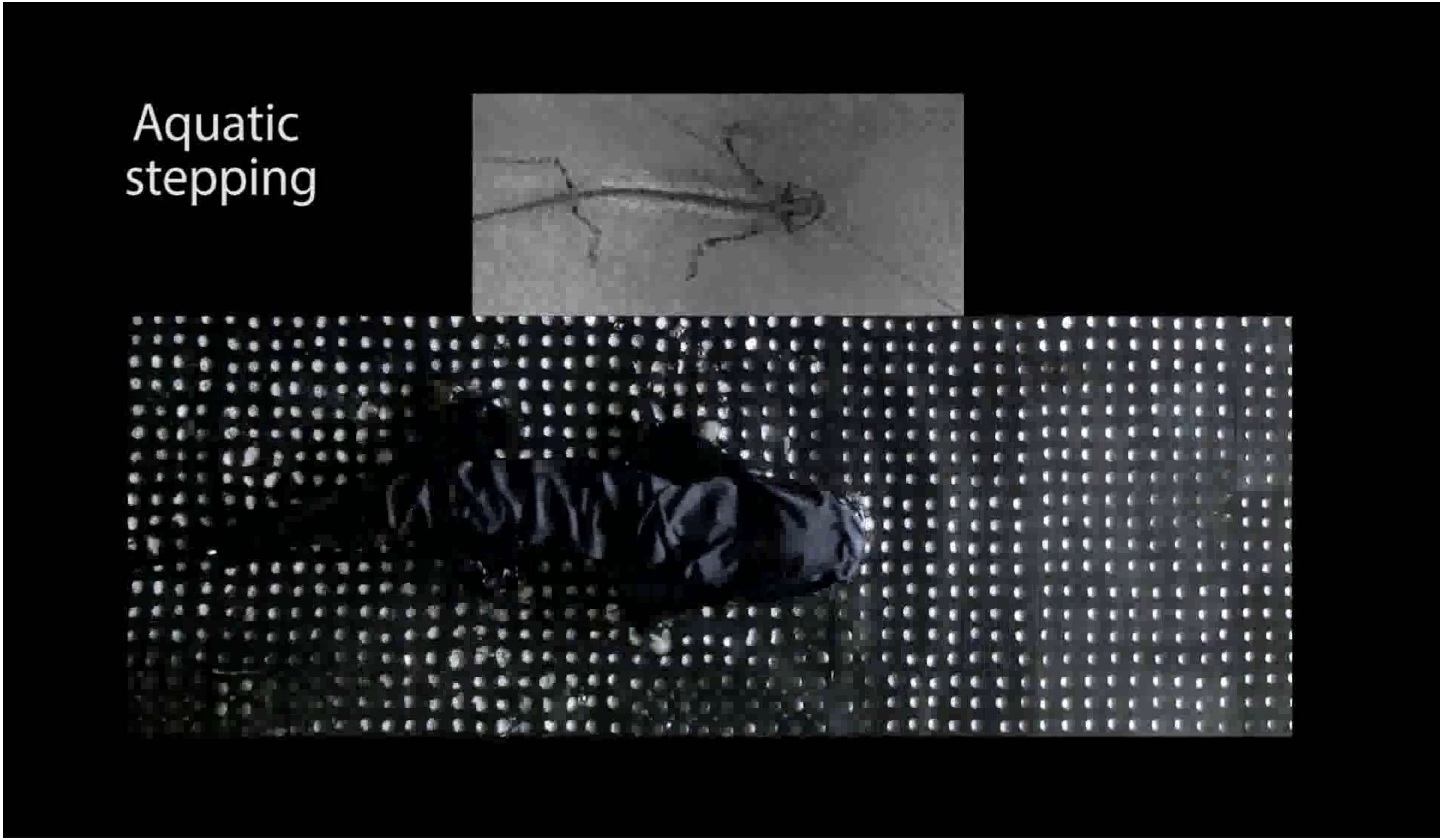
Animal Aquatic Stepping

Pleurobot Aquatic Stepping



Hypothesis

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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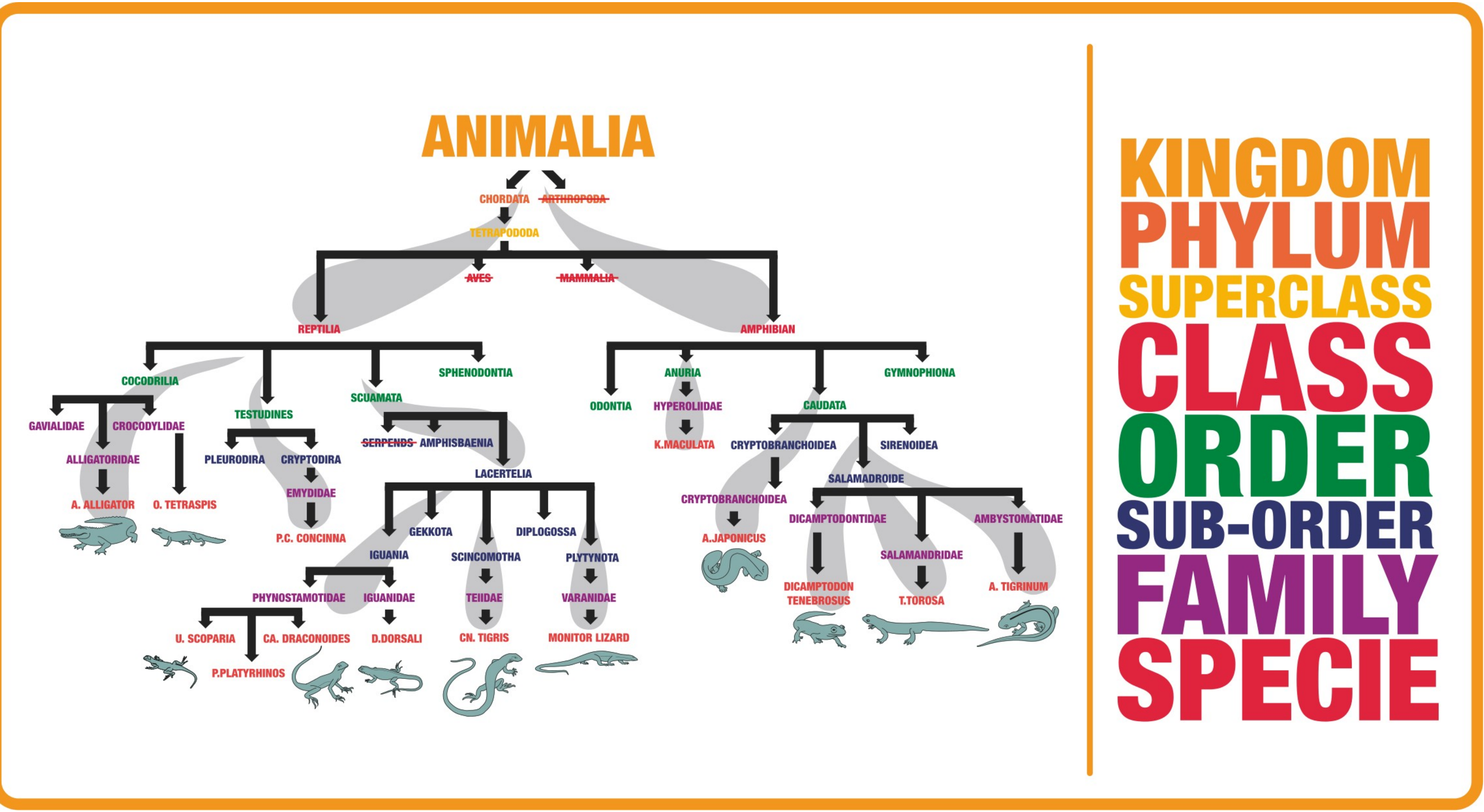
Systematic selection of representative species (Sprawling posture, undulatory spine)

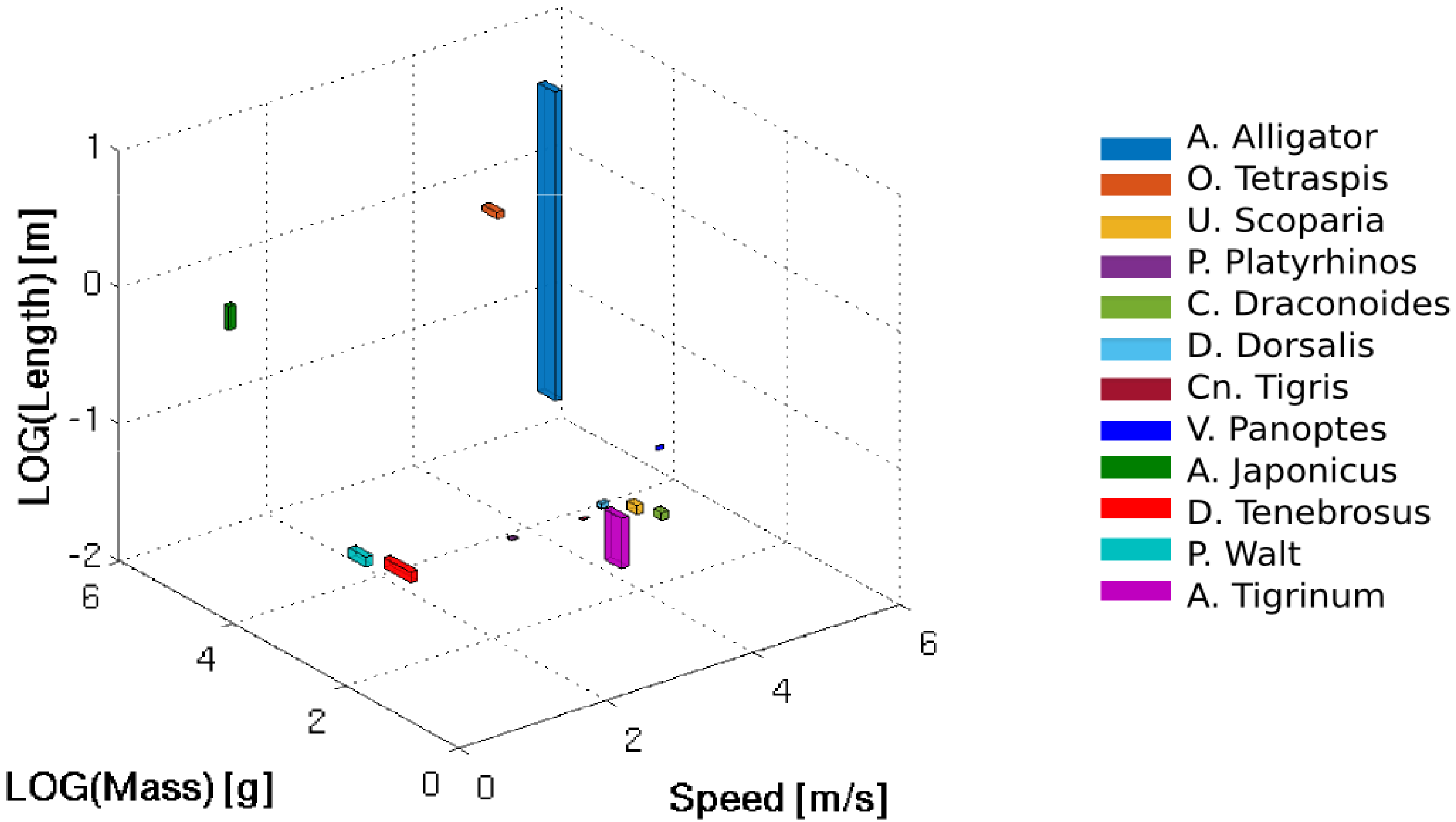


Clustering of species by biomechanic evaluation

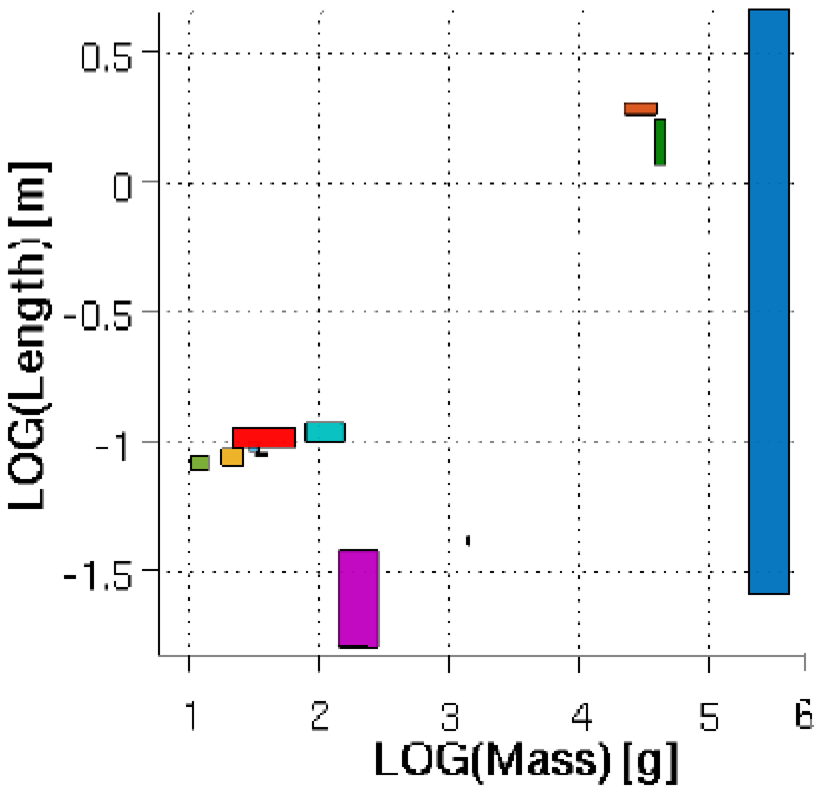
	A. mississippiensis	**O. tetraspis**	**U. scoparia**	**P. platyrhinos**
Speed (m/s)	6.667	4.722	3.8-4.1	2.0-2.2
Mass (g)	$(181\text{-}363)\mathrm{x}10^3$	$(18\text{-}32)\mathrm{x}10^3$	20.22-13.78	23.03-28.37
Length (m)	0.025- 4.5	1.7 - 1.9	0.074-0.086	0.078-0.079
Source	[3]	[4]	[5]	[5]
	C. draconoides	**D. dorsalis**	**Cn. tigris**	**V. panoptes**
Speed (m/s)	4.1-4.3	3.6-3.7	3.15-3.25	6.3
Mass (g)	8.0-11.0	22.35-25.65	16.3-18.3	1243
Length (m)	0.071-0.081	0.083-0.091	0.085-0.086	0.041
Source	[5]	[5] [6]	[5]	[7]
	A. japonicus	**D. tenebrosus**	**P. waltl**	**A. tigrinum**
Speed (m/s)	0.32	0.062-0.279	0.053	4.722
Mass (g)	$(25\text{-}30)\mathrm{x}10^3$	14-42	50-100	113-227
Length (m)	1-1.5	0.081 0.096	0.085-0.1	0.015-0.035
Source	[8]	[9] [10]	[11]	[12]

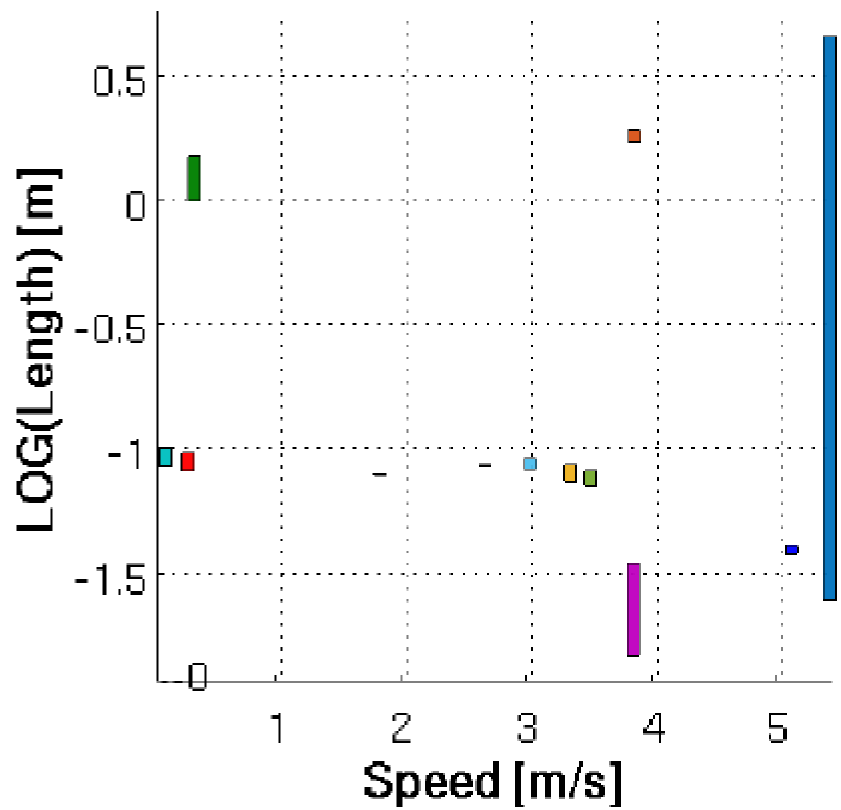
Table 2.1: Parameters of selected species

Clustering of species by biomechanic evaluation



Clustering of species by biomechanic evaluation

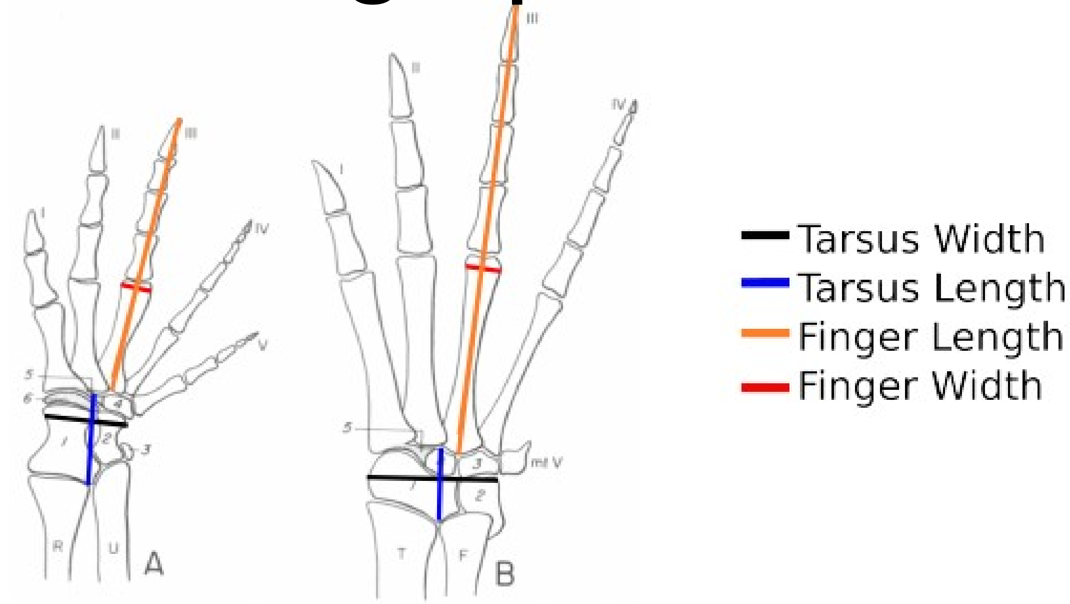




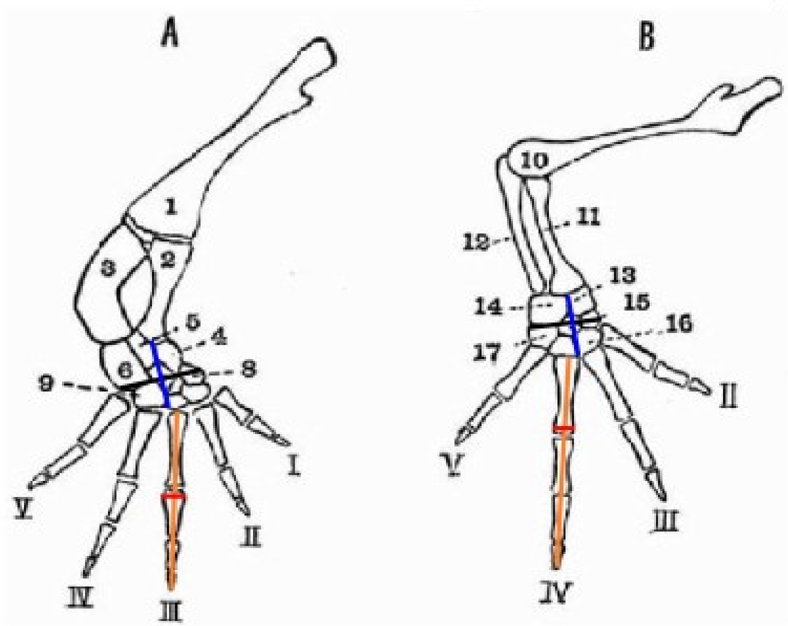
scratch-robot-design purposes

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

Foot design parameters



(a)



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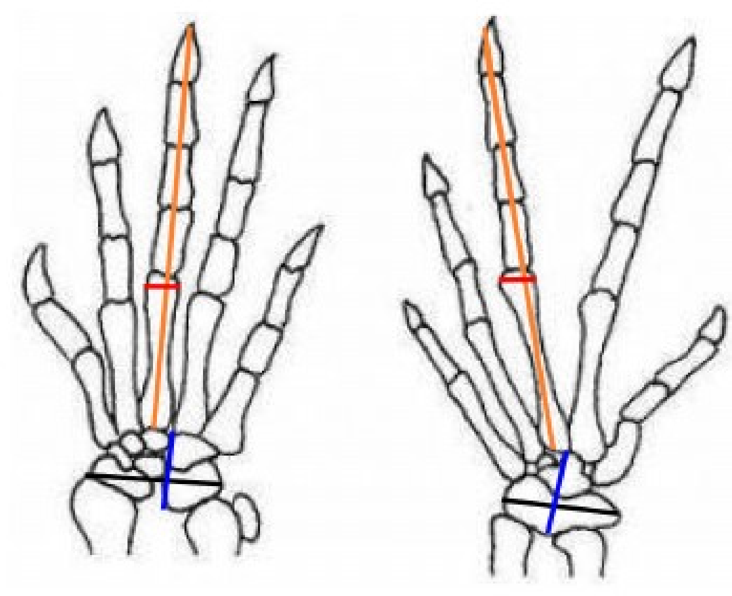

(c)

Foot design parameters

ForeLimb					
Animal	**Family**	**Tarsus Width**	**Tarsus Length**	**Finger Length**	**Finger Width**
Lizard	Phrynosomatidae	5.07	3.67	9.54	1.00
	Iguanidae	3.66	3.03	13.39	1.00
	Scincomorpha (subOrder)	3.45	2.72	8.70	1.00
	Varanidae	3.21	1.67	6.61	1.00
Salamander	Cryptobranchoidea	3.52	1.97	3.37	1.00
	Dicamptodontidae	3.15	2.45	7.55	1.00
	Salamandridae	3.97	3.56	11.20	1.00
	Ambystomatidae	3.02	2.80	6.02	1.00
Alligator & Crocodile	Alligatoridae	2.81	2.98	9.11	1.00
	Crocodylidae	4.02	4.29	14.65	1.00

HindLimb					
Animal	**Family**	**Tarsus Width**	**Tarsus Length**	**Finger Length**	**Finger Width**
Lizard	Phrynosomatidae	4.40	3.01	18.56	1.00
	Iguanidae	4.17	3.78	21.16	1.00
	Scincomorpha (subOrder)	4.29	2.43	16.56	1.00
	Varanidae	5.17	3.00	8.41	1.00
Salamander	Cryptobranchoidea	3.02	2.12	5.24	1.00
	Dicamptodontidae	3.81	3.45	9.08	1.00
	Salamandridae	4.30	4.48	11.70	1.00
	Ambystomatidae	4.90	4.76	8.74	1.00
Alligator & Crocodile	Alligatoridae	4.88	3.56	17.81	1.00
	Crocodylidae	5.14	2.16	18.38	1.00

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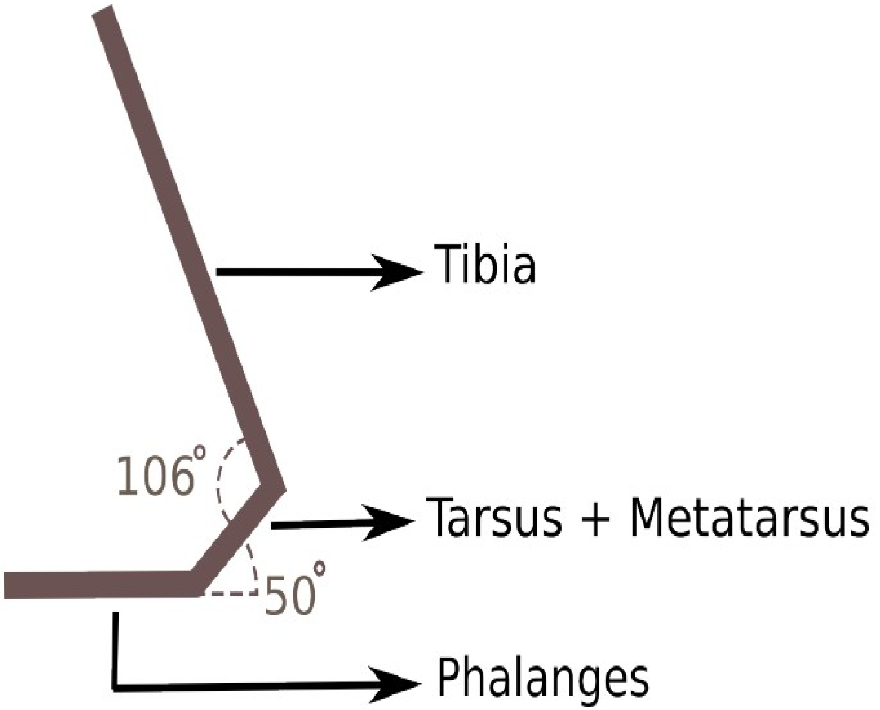
Animal species and features design selection

Tiger salamander (*Ambystoma tigrinum*)

Bone structure and bone dimensions

Data related to the kinematics of the stride

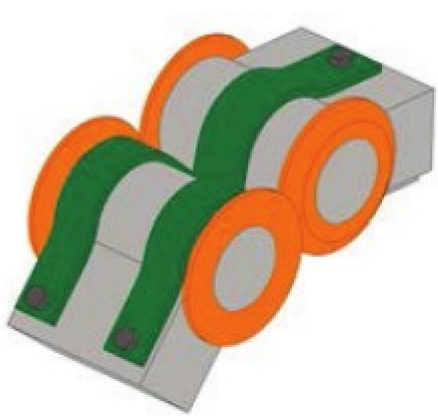
Measurements of ground reaction forces (GRF)



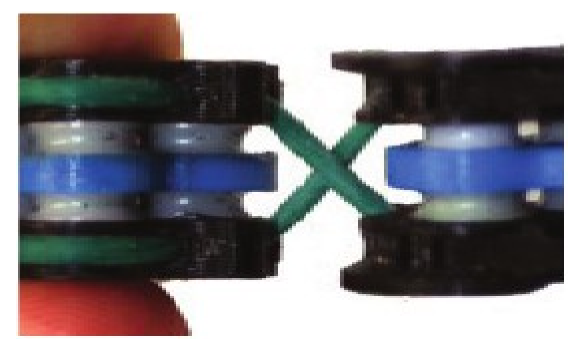
Technology Selection

Hillberry Joint

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



Pisa/IIT SoftHand

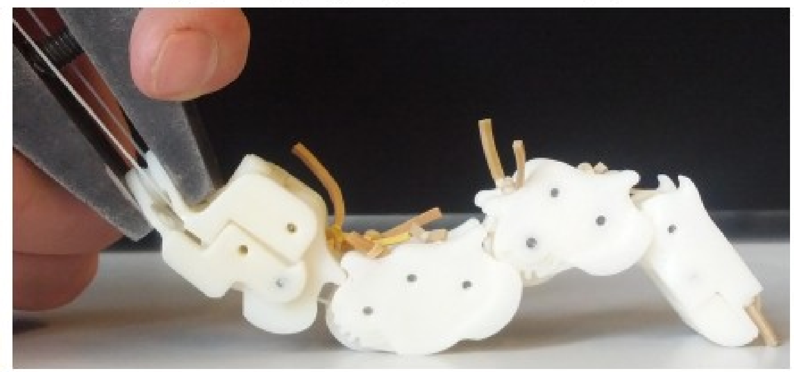


Finger design

(a) Angle on last phalange and metatarsus

(b) Applying force to (a)

(c) Angle on last phalanx



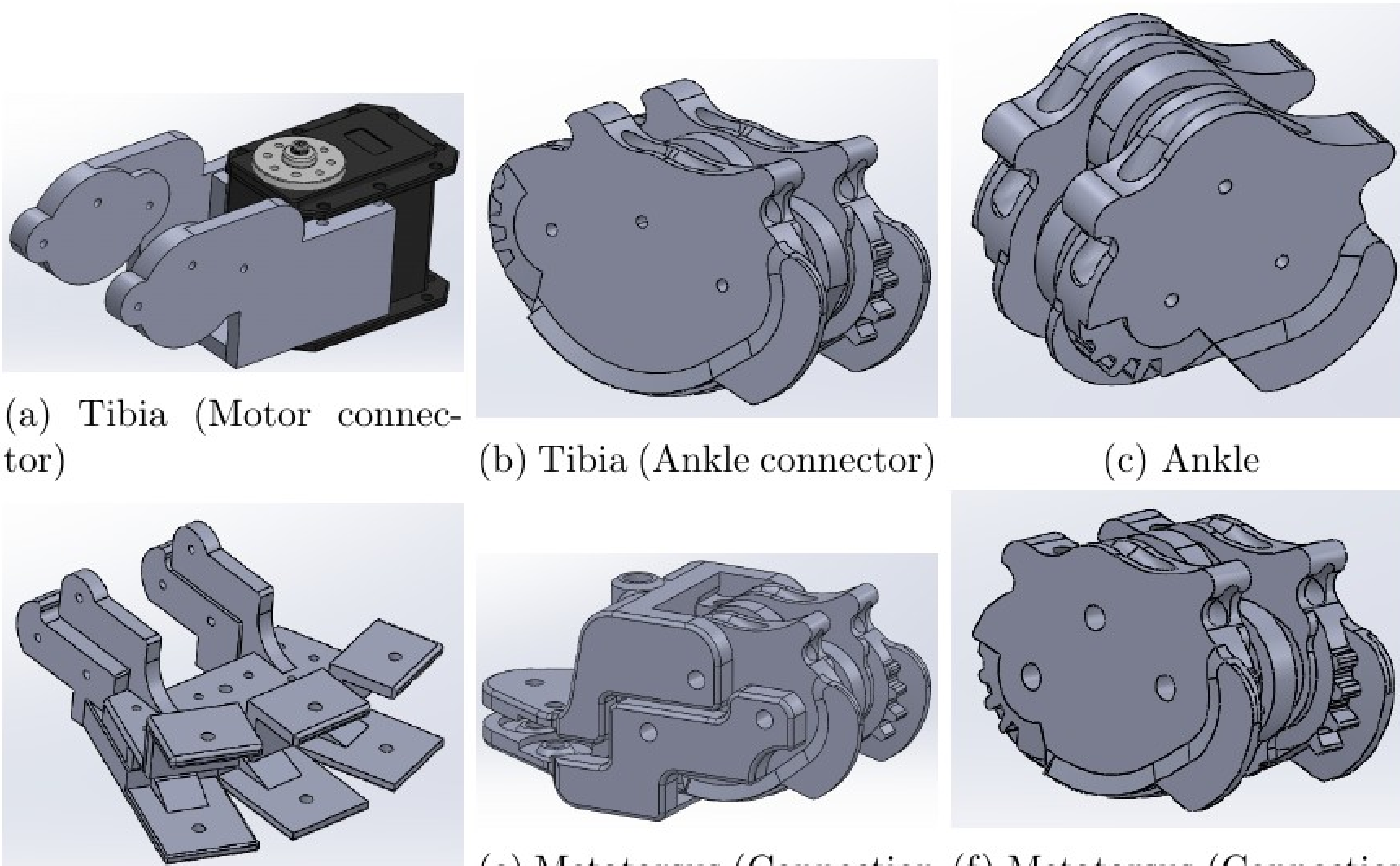
(d) Applying force to (c)

(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

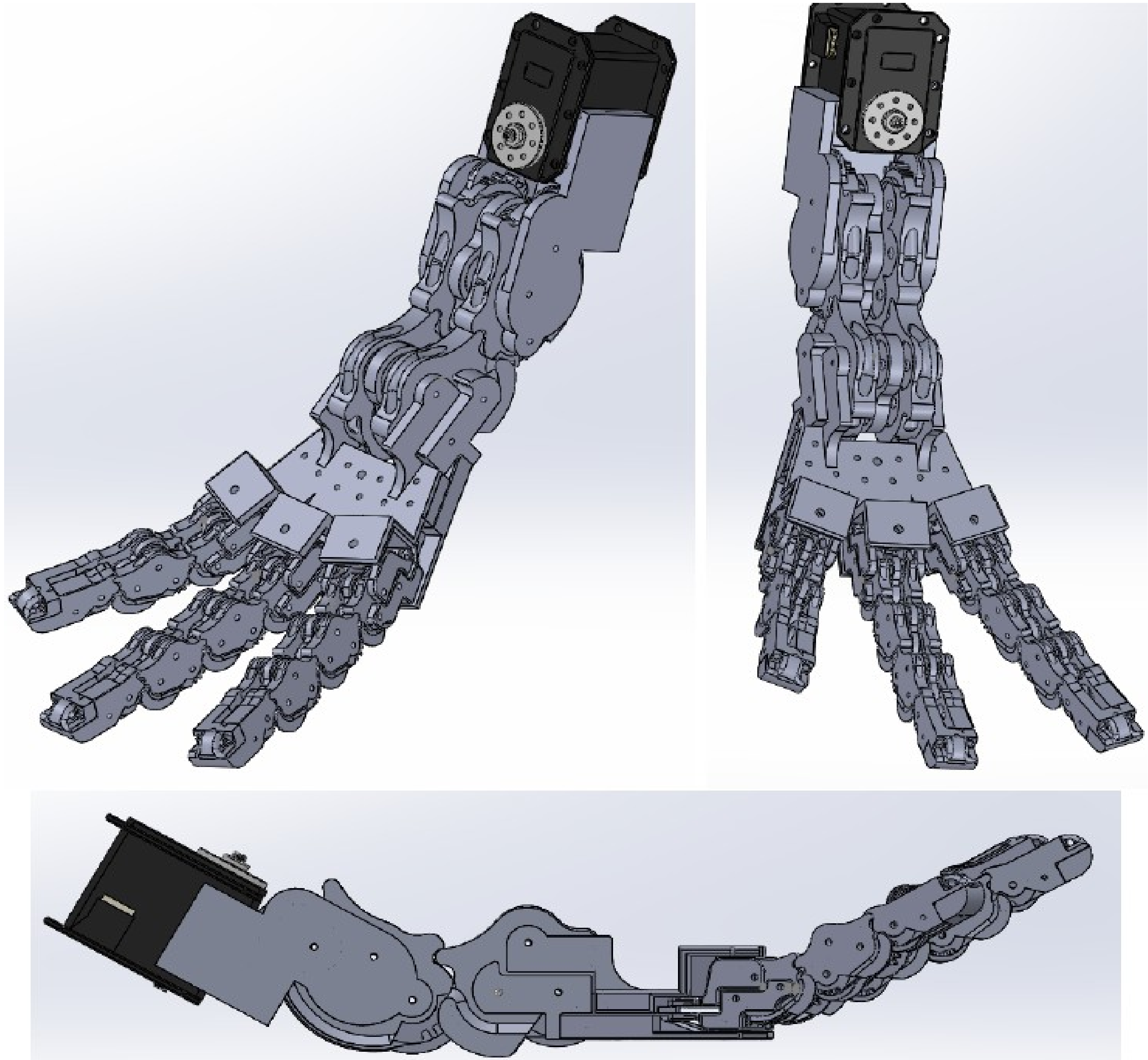
(d) Tarsus (Palm)

(e) Metatarsus (Connection with Tarsus)

(f) Metatarsus (Connection with Phalanx

Figure 3.3: Mechanical parts

Final Foot Design.



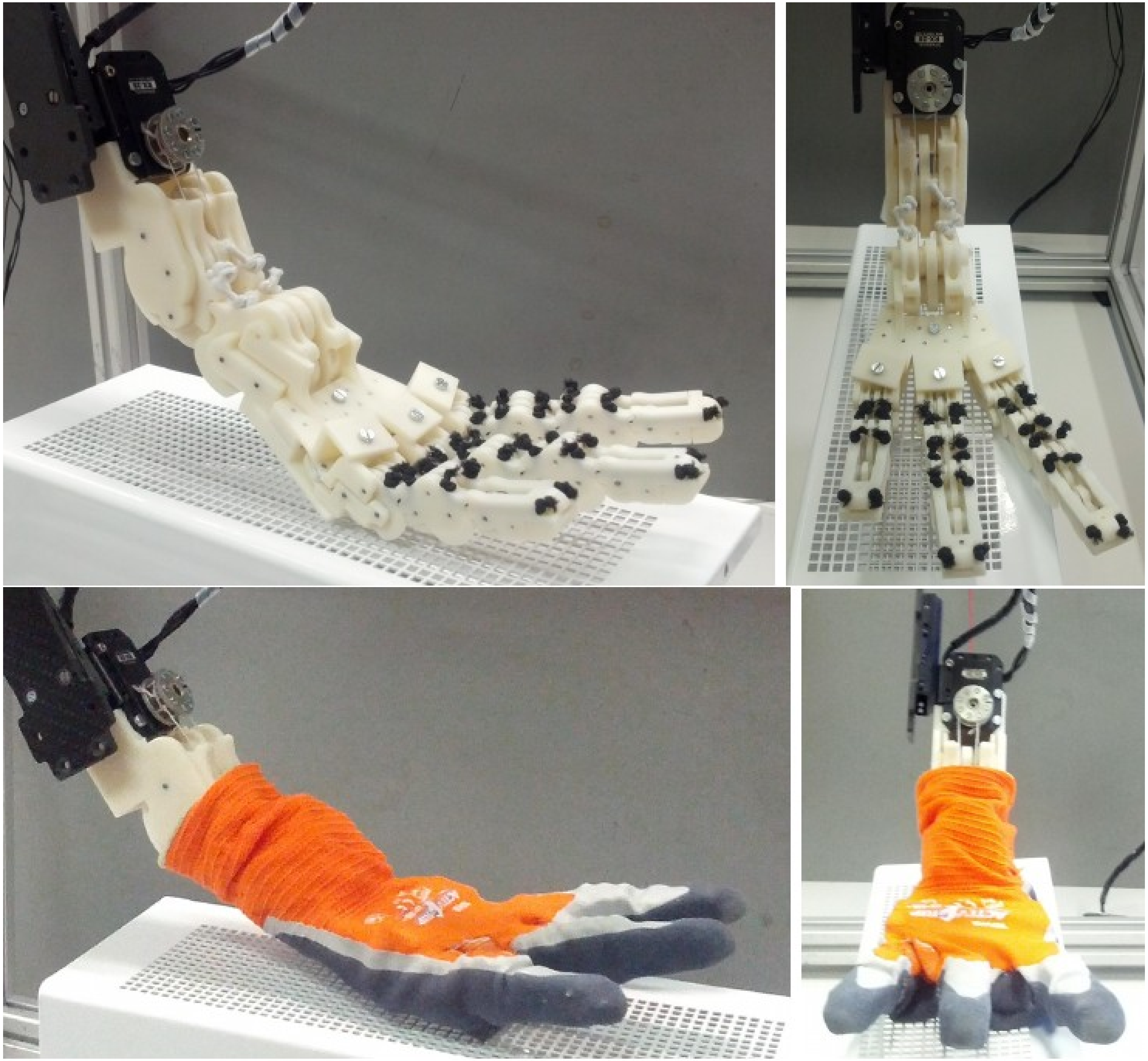


Figure 3.5: Foot implemented

Animal vs Robotic Foot

	Tarsus Width	Tarsus Length	Finger Length	Finger Width
Normalized parameters	4.90	4.76	8.74	1.00
Using Finger Width=10.25 (mm)	50.2	48.8	89.6	10.2
Measures foot robot implementation (mm)	50	58	100	10.2
Error (absolute and [%])	0.2 [0.4%]	10.8 [18%]	10.4 [10%]	0 [0%]

Table 3.1: Comparison measures

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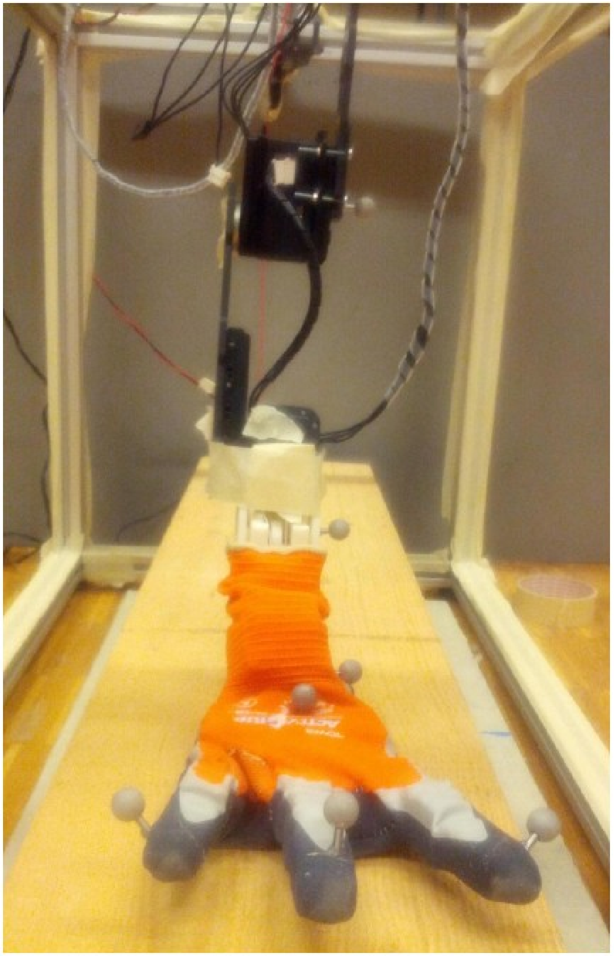
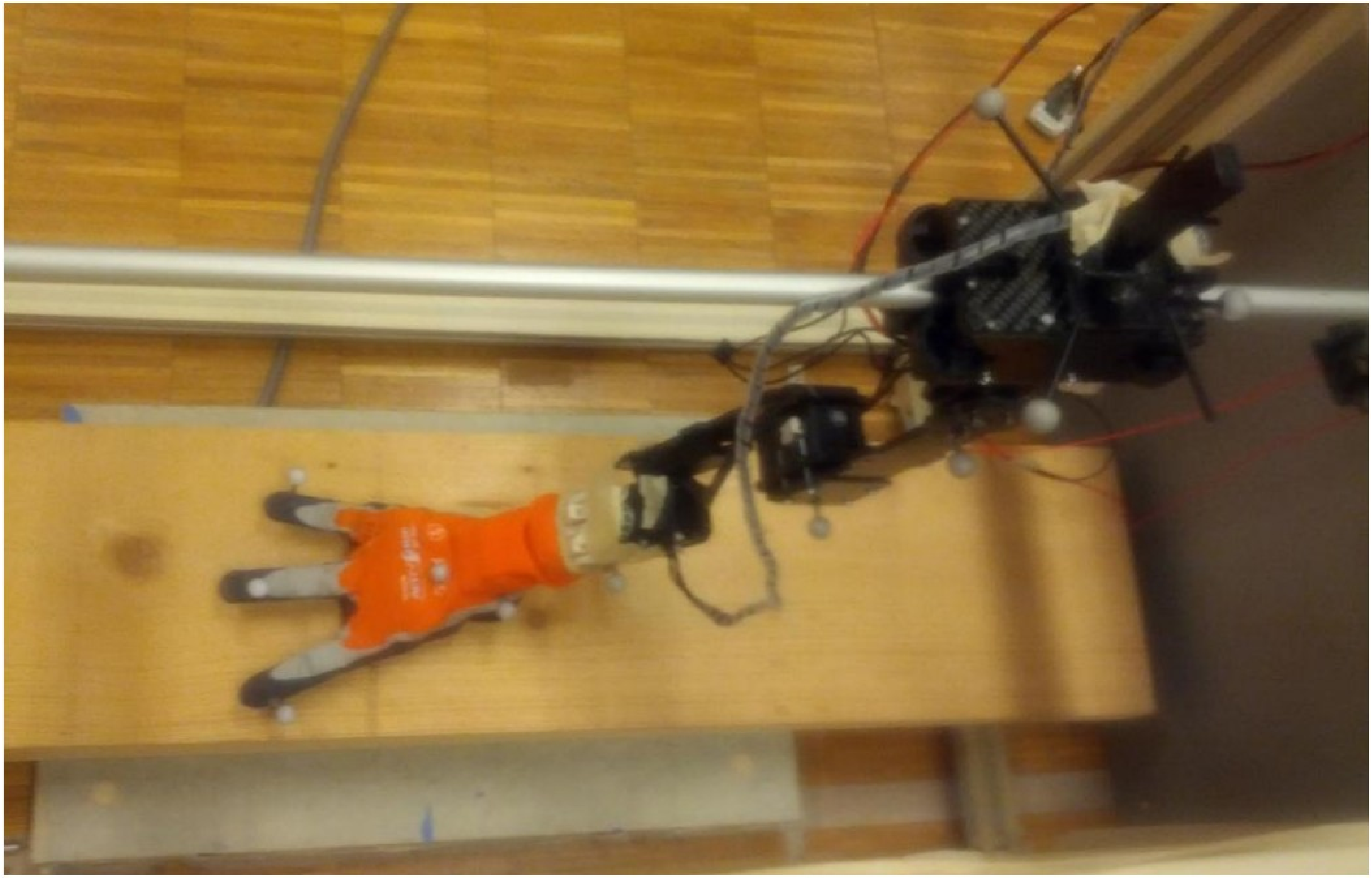
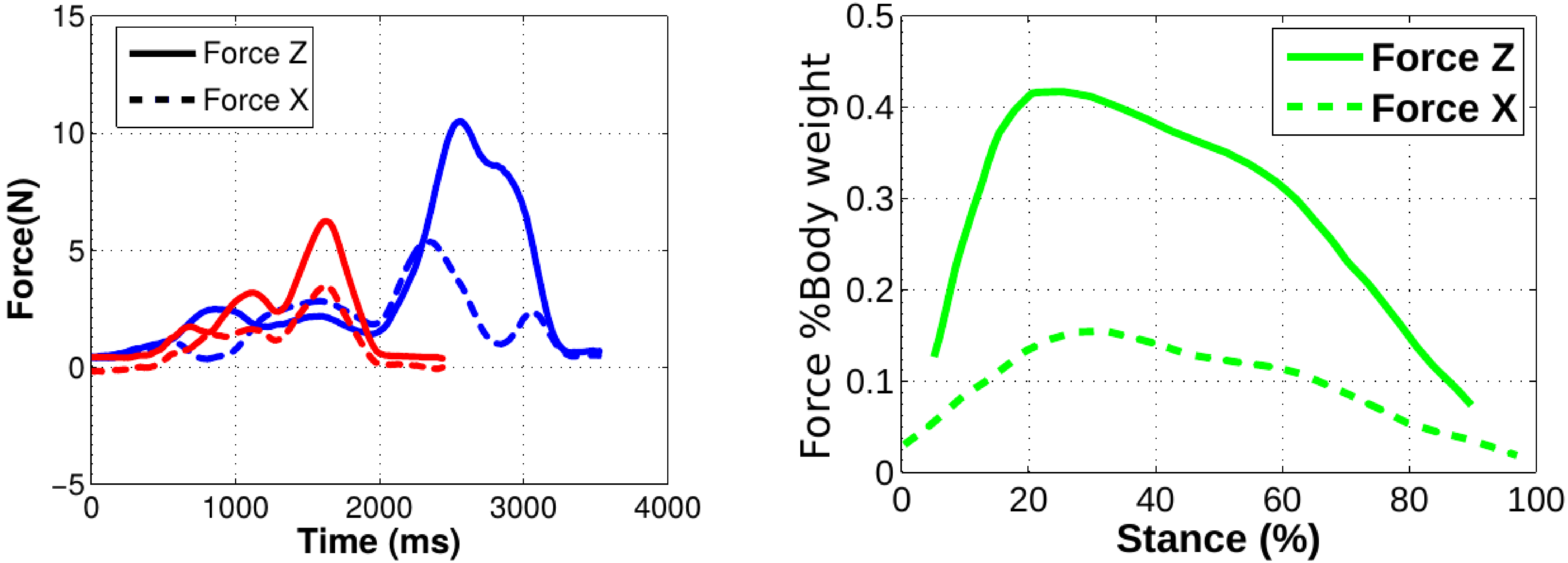
Set up

Experiment





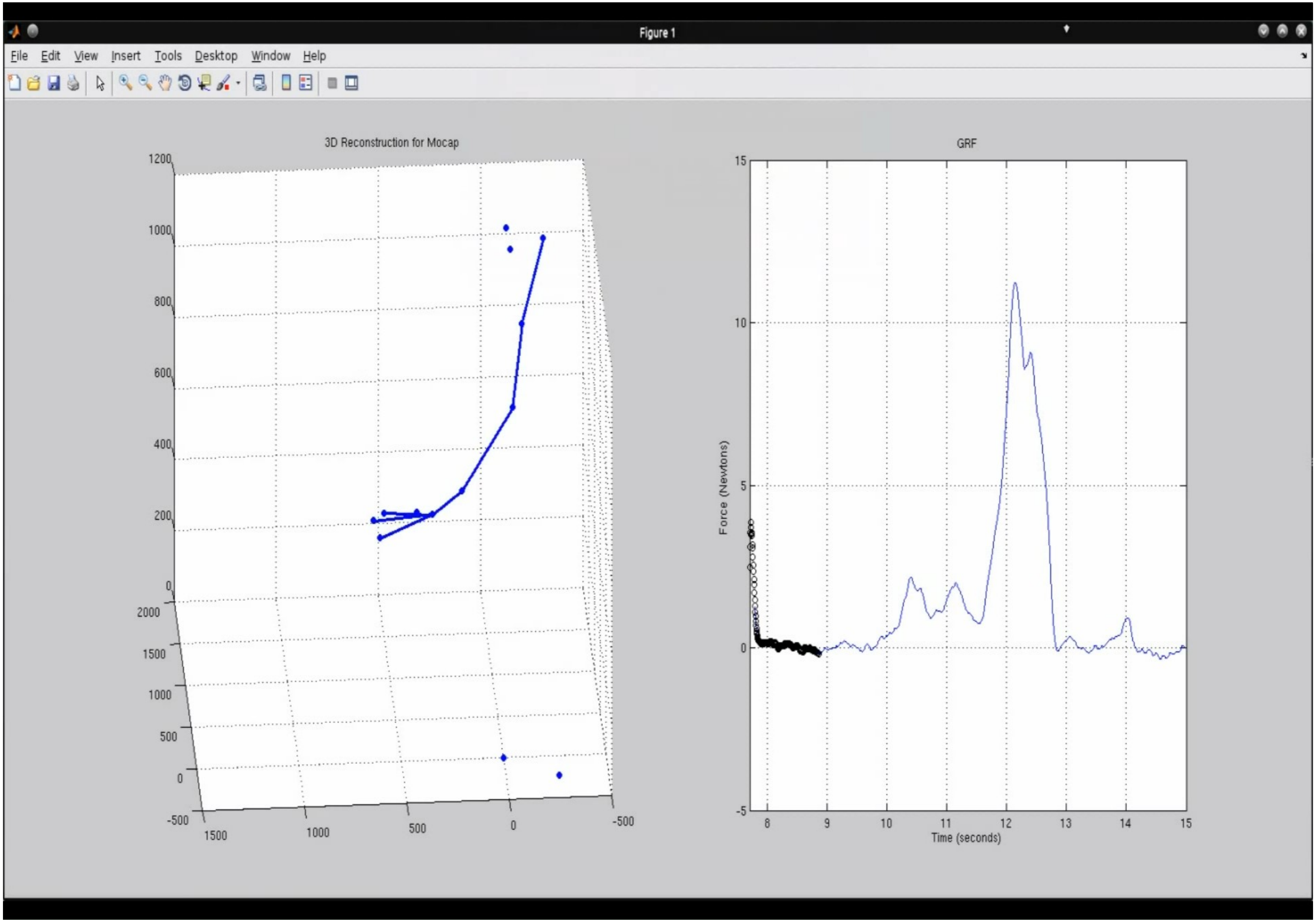
Ground Reaction Forces



(a) (b)

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

Extra features

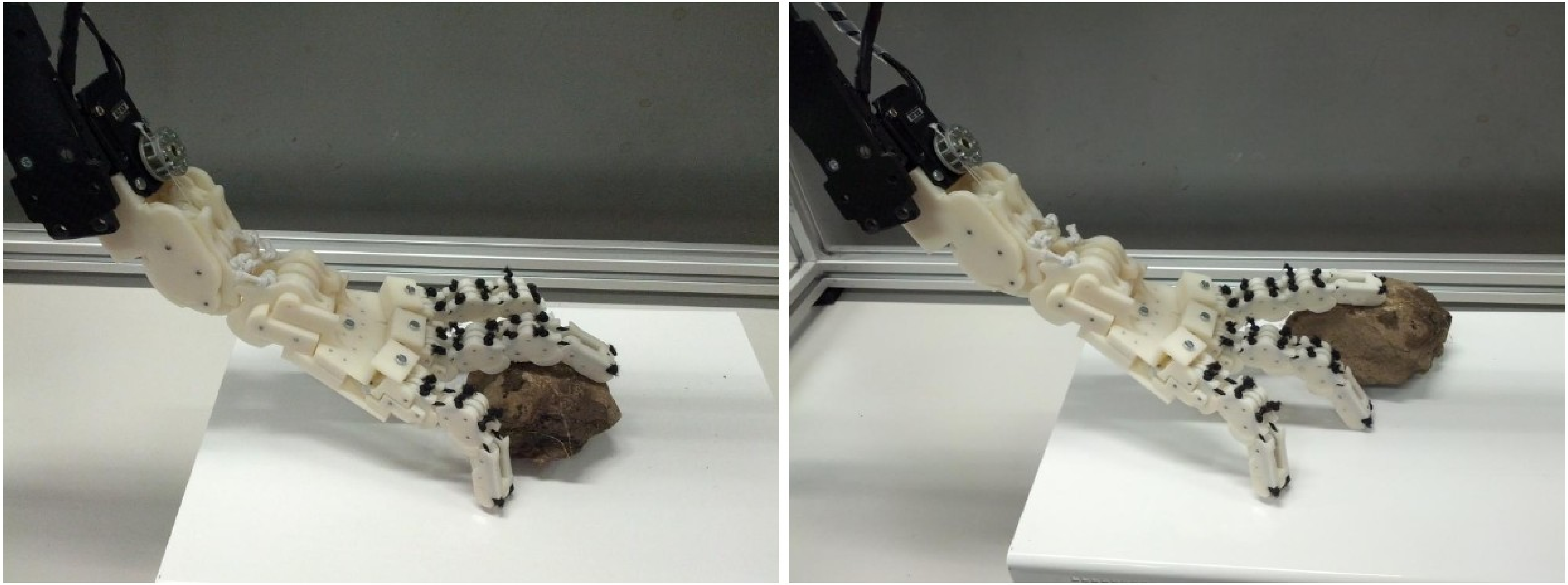


Figure 4.6: Left, two fingers on a rock while the third one adapts to the floor. Right, the same experiment but using only one finger on the rock.

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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 i**mpact 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**.

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Questions?