Study on Elastic Elements Allocation for Energy-Efficient Robotic Cheetah Leg

“Attendance in IROS 2019”

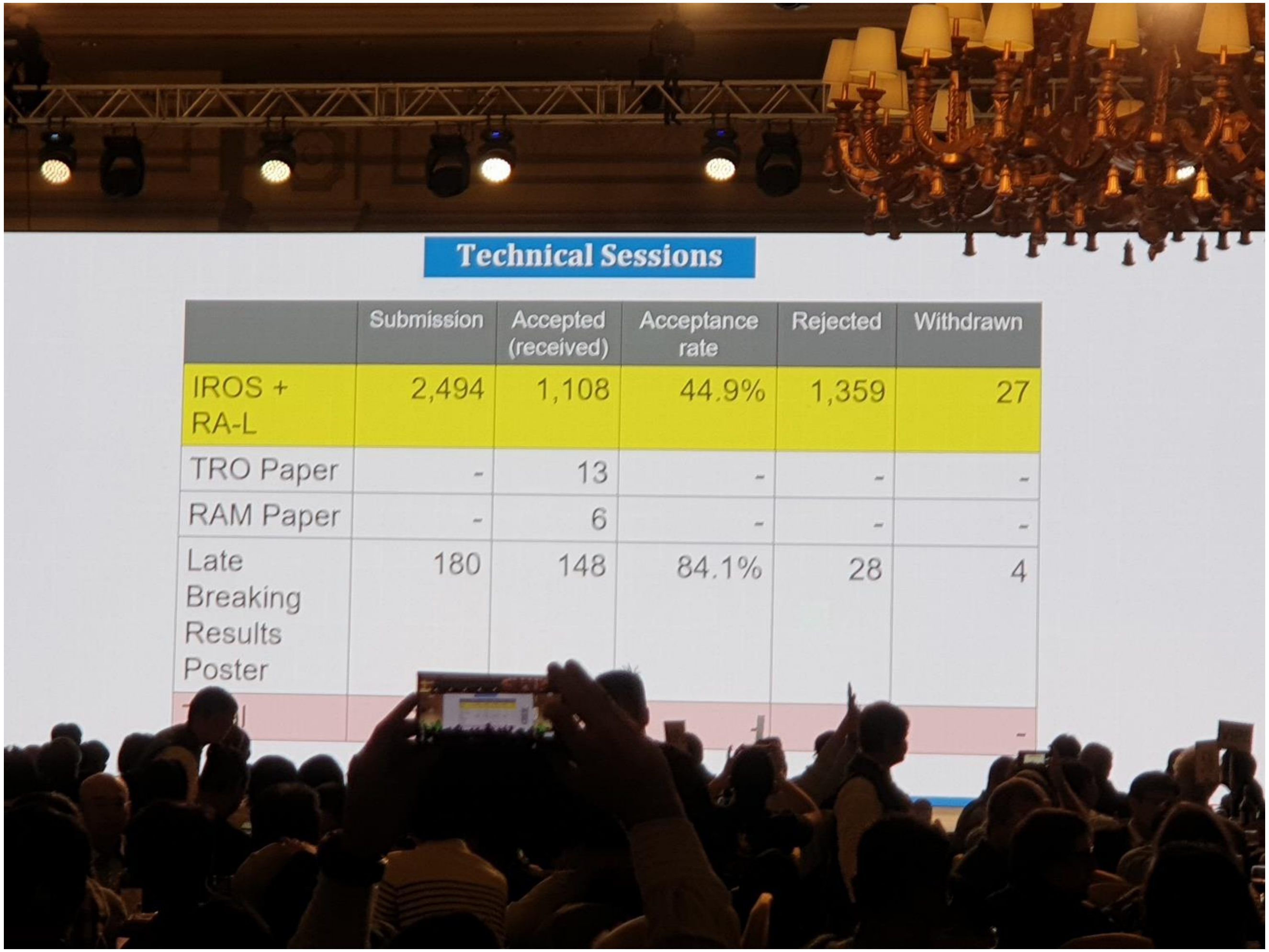
Junseok Lee

2019. 11. 20.

Borisov, I. I., Kulagin, I. A., Larkina, A. E., Egorov, A. A., Kolyubin, S. A., & Stramigioli, S., “Study on Elastic Elements Allocation for Energy-Efficient Robotic Cheetah Leg,” In *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 1696-1701, Nov., 2019

Information of the IROS 2019

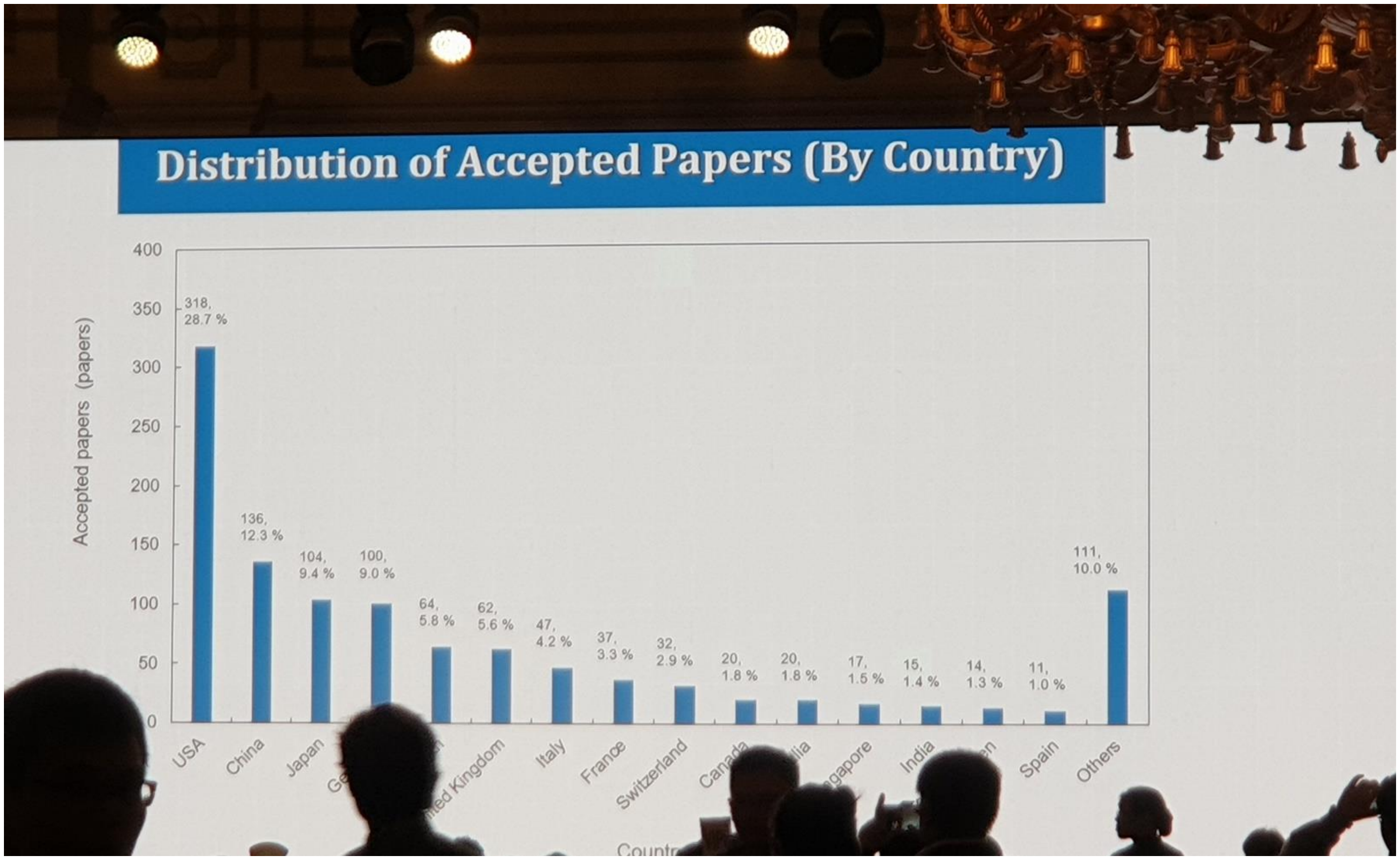
- Acceptance rate of the papers



	Submission	Accepted (received)	Acceptance rate	Rejected	Withdrawn
IROS + RA-L	2,494	1,108	44.9%	1,359	27
TRO Paper	-	13	-	-	-
RAM Paper	-	6	-	-	-
Late Breaking Results Poster	180	148	84.1%	28	4

Information of the IROS 2019

- Acceptance rate by each country
  - Korea: 5th grade



Introduction

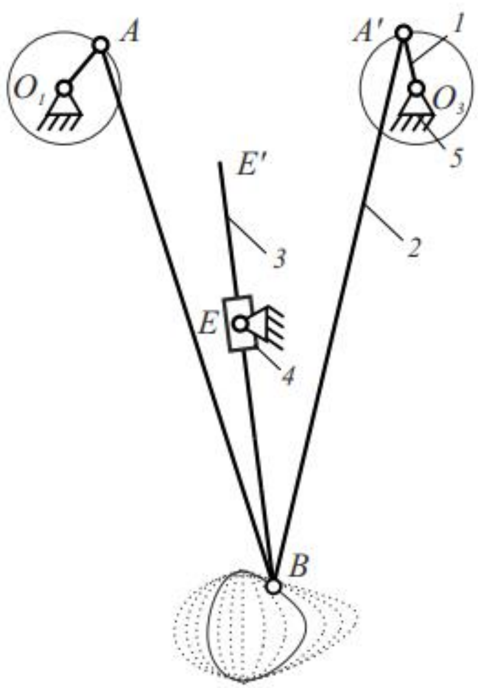
- Wheel-based mobile robots are used in many applications providing advantages, such as low energy consumption, high forward speed, and precision
- The focus of this paper is on the biomimetic legged locomotion and development of an energy-efficient cheetah robot
- Reducing cost of transport of legged locomotion

Desired Behavior

- The knee joint bends to absorb the impact force
- The legs push the body to the flight phase taking the body forward over the rear leg
- The rear legs are more muscular than the front and they are mostly responsible for the push off motion
- As for the front legs, their main function is to keep the body at a certain distance from the ground

Prior art in femur mechanism design

- The goal is to design a simple planar leg mechanism with a minimal number of actuators and links
- The mechanism has two degrees of freedom (DOF)



The femur mechanism of the cheetah robot leg

(1) Cranks

(2) Connecting rods

(3) Crank arm

(4) Brick

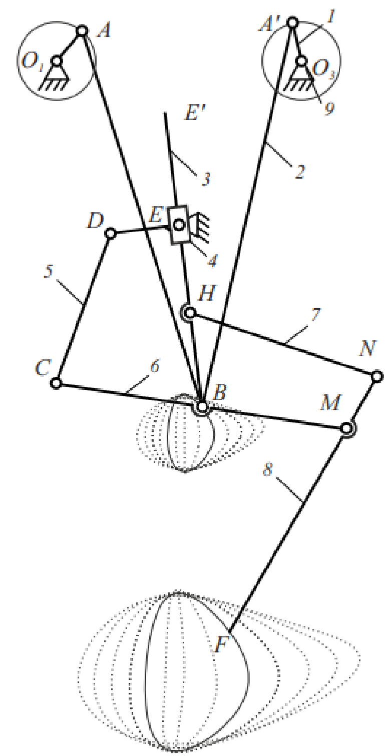
(5) frame

Full Leg Mechanism Design

- To create a more cheetah-like full leg mechanism, which is able to provide the faster acceleration and speed
- A full leg design based on the "Minitaur" structure and real cheetah anatomy
- Tibia, a fibula, and a metatarsal should be added to the Minitaur femur mechanism to create a full leg structure

The mechanism of the leg along with changing in trajectory

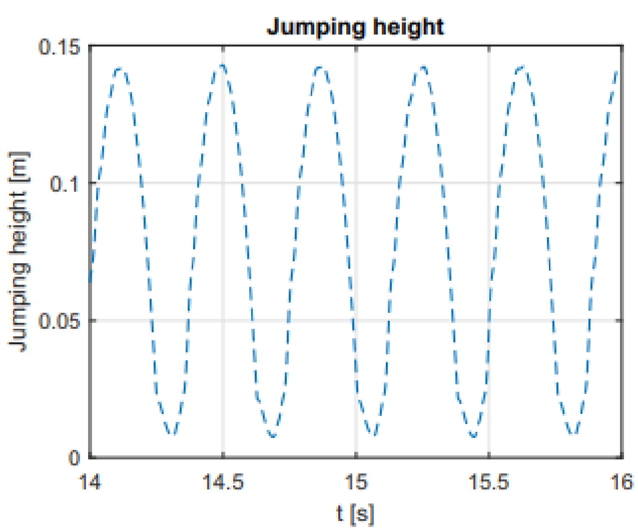
(1) Cranks
(2) Connecting rods
(3) Crank arm
(4) Brick
(5) Sartorius
(6) Tibia
(7) Fibula
(8) Metatarsal
(9) Frame

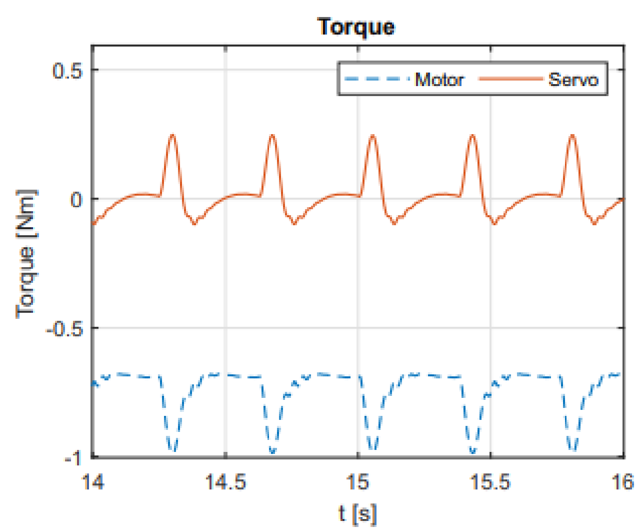


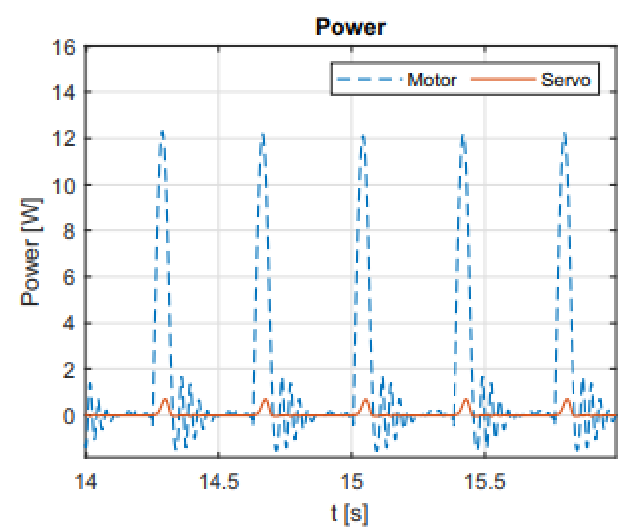
KAIST
URBAN ROBOTICS LAB

Simulation-Based Mechanism Analysis

- Actuator model
  - To control the positions of the cranks two PID controllers are implemented for the servo and the DC motor respectively
  - Control torques are calculated based on the difference between the desired and computed motor's and servo's angles and then sent into electrical blocks modeling the PWM transformer and the H-Bridge

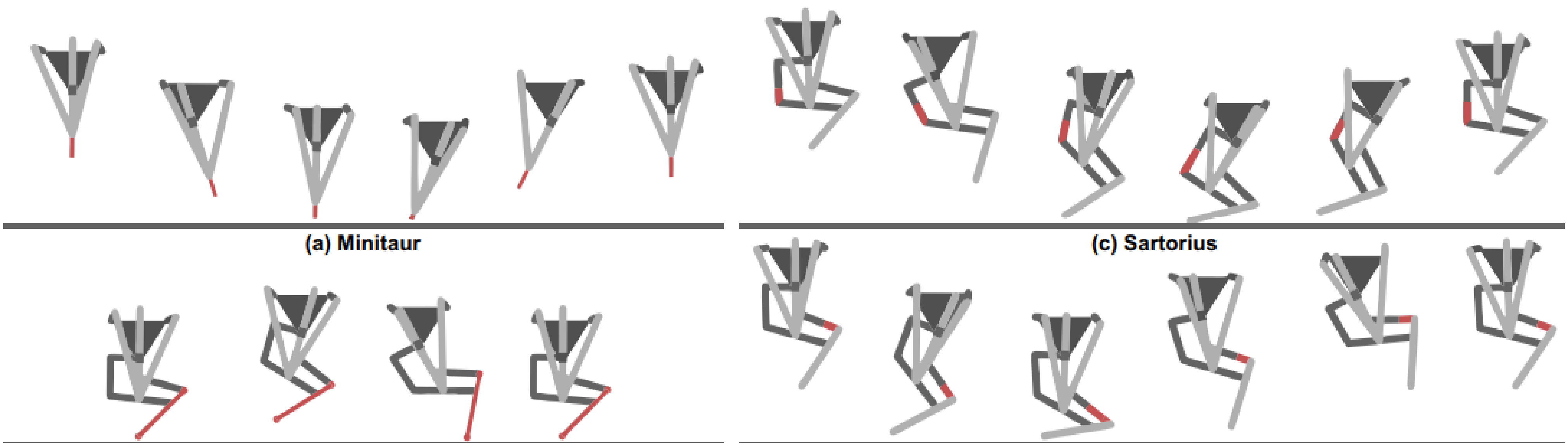






Simulation-Based Mechanism Analysis

- Femur mechanism case study
  - Step size: 0.26 rad
  - Stable height: 14 cm
  - Maximum horizontal velocity: 1 m/s



(a) Minitaur (b) Metatarsal (c) Sartorius (d) Fibula

Simulation-Based Mechanism Analysis

- Leg mechanism case study
  - Link MF can be considered as a metatarsal, it can be studied as a flexible body, while others links are rigid bodies
  - Link DC can be considered as sartorius and built as a spring on a prismatic joint, while others links are rigid bodies
  - Link HN can be presented as a fibula and built as a spring on a prismatic joint, while others links are rigid bodies

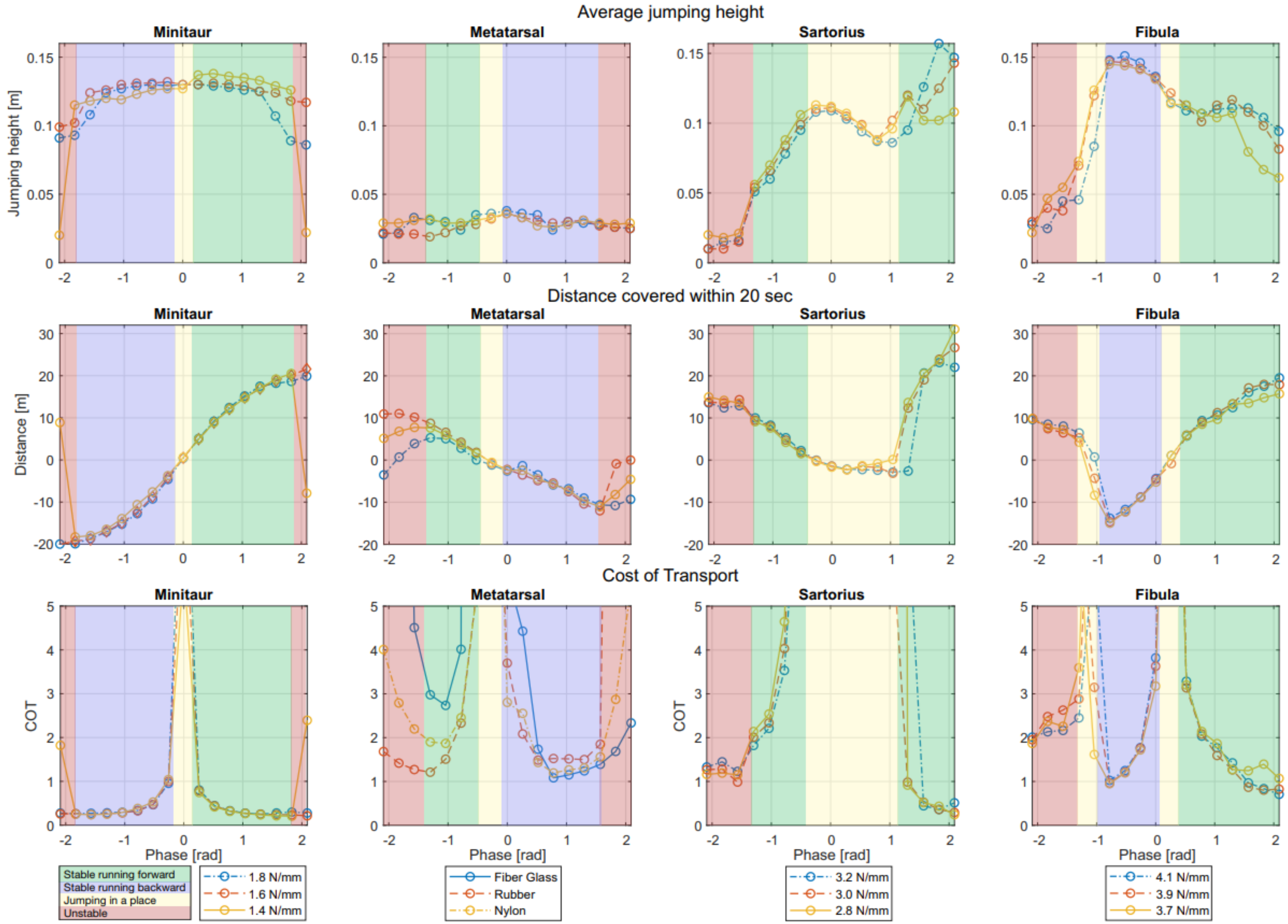
Simulation-Based Mechanism Analysis

- Materials for legs

Material	Nylon	Rubber	Glass fiber
Young's Modulus (E, GPa)	2	0.5	72
Poisson's Ratio(v)	0.39	0.48	0.21

Simulation-Based Mechanism Analysis

- Materials



KAIST

URL URBAN ROBOTICS LAB

Conclusion

- Analysis of the Minitaur femur mechanism and the cheetah-inspired full leg structure for a energy-efficient galloping motion
- Galloping robot leg structures inspired by cheetah morphology and studied the best flexibility
- The best design in terms of horizontal velocity and energy efficiency is the sartorius-allocated flexibility with stiffness coefficient K_3 = 2.8 N/mm, actual damping coefficient β=1 Nm/s , and phase difference 2.09 rad.
- The highest achievable velocity is up to 1.5 m/s

Thank you for your very kind attention