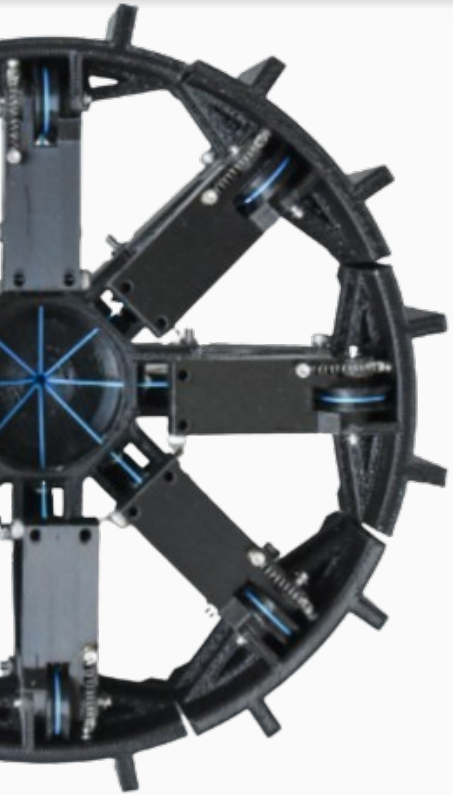
GRIEEL STABILITY

Final Presentation
August 5, 2024

Alessandro Puglisi

Supervised by:
Prof. Kazuya Yoshida
Assistant Prof. Shreya Santra, Kentaro Uno

AGENDA



- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Self-Introduction

Alessandro Puglisi, 23
Home country: Italy
COLABS exchange student.

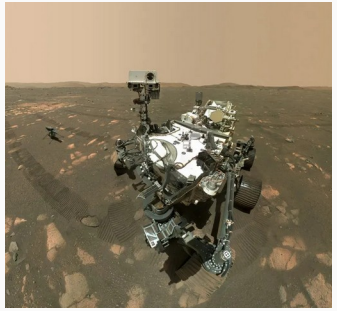
Politecnico di Milano,
Automation and Control engineering [M2]

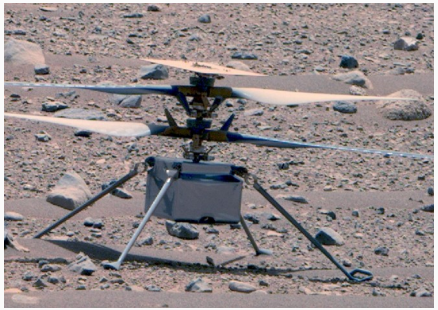
Background in Control systems and Robotics.
Interest: Mobile Robot in hazard and uneven terrains

Resarch Importance

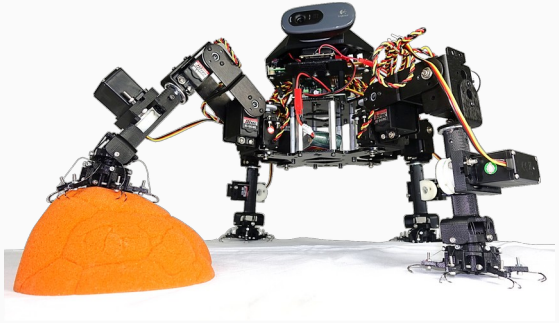
The SPACE ROBOTICS LAB

- Different locomotions for different environment.
- Bio-inspired robotics takes over
- Smooth locomotion transition?





GRIEEL

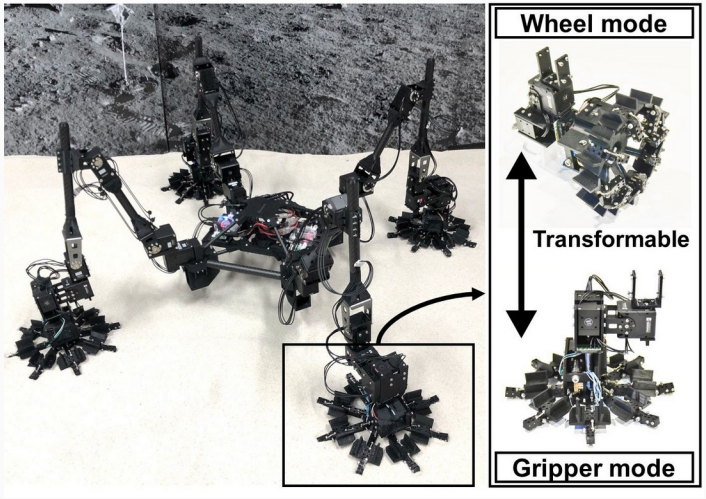


Legged Robot:
- Rough terrain traversability
- Climb cliffs by grippers

Wheeled Robot:
- move faster by wheel
- more efficent locomotion

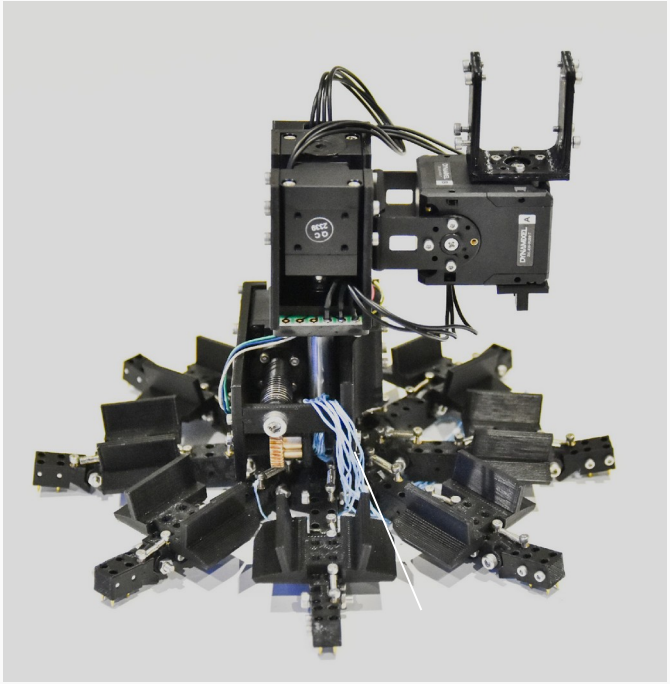
Transformable module
GRIpper + whEEL = GRIEEL

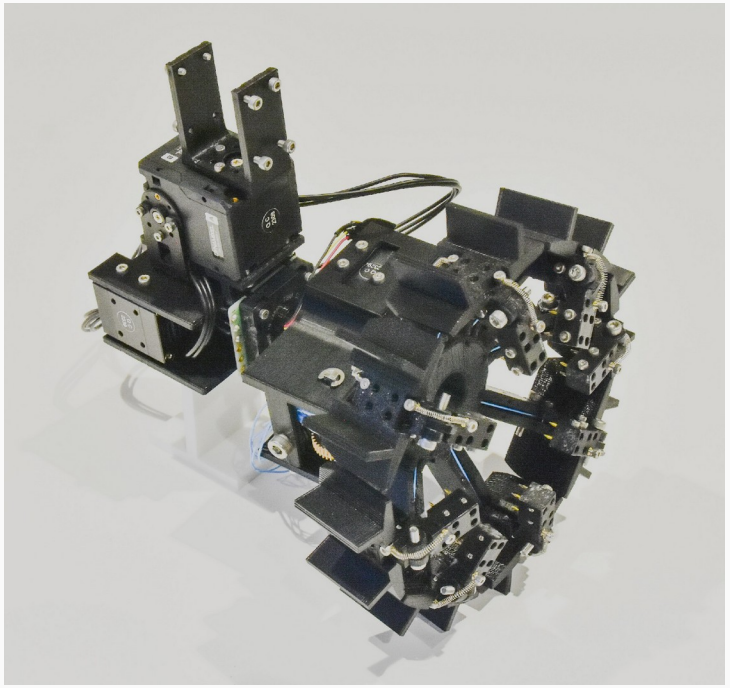
As LIMBERO end-effector



GRIEEL

The SPACE ROBOTICS LAB





AGENDA

- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Software architecture

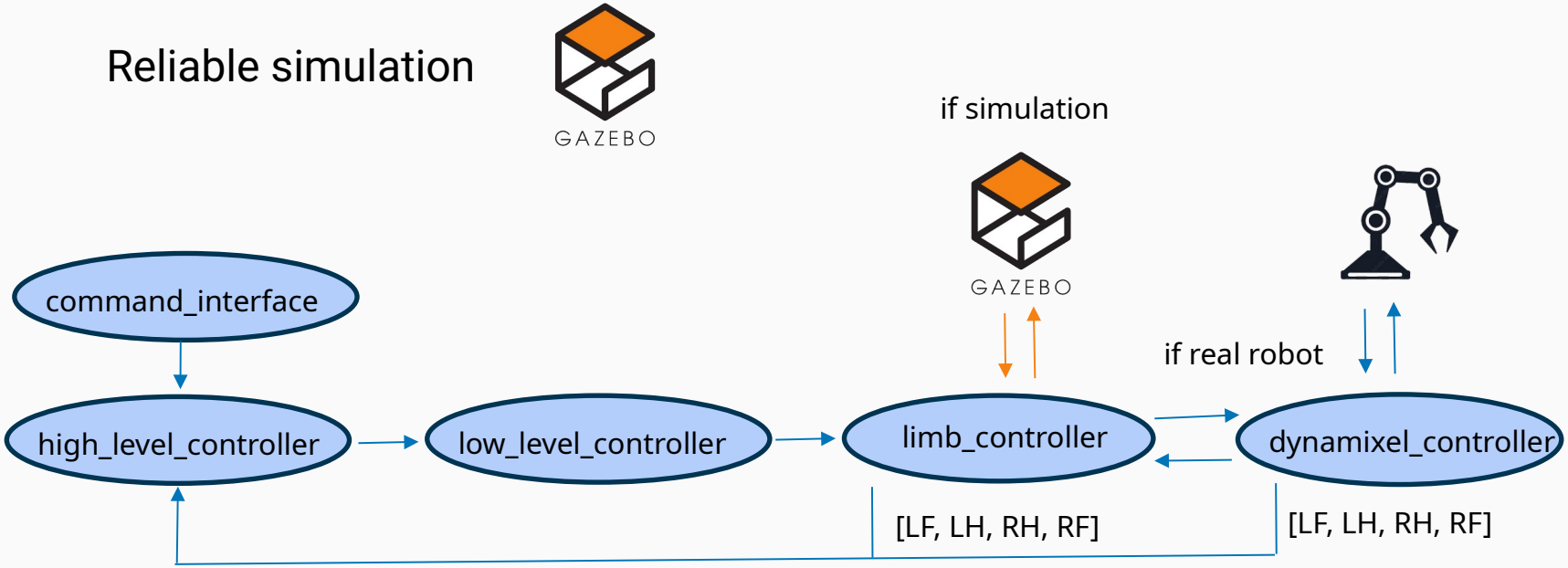
The SPACE ROBOTICS LAB

comunication and computation

ROS 2

Reliable simulation

GAZEBO



AGENDA

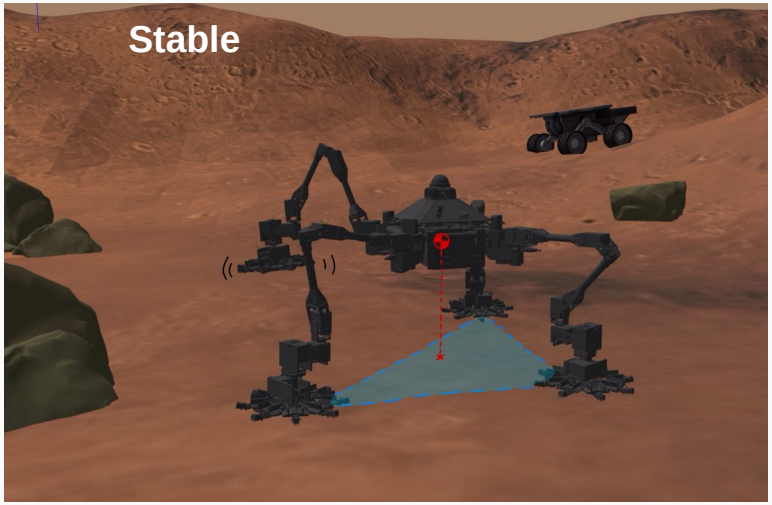
- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Stable mode transition

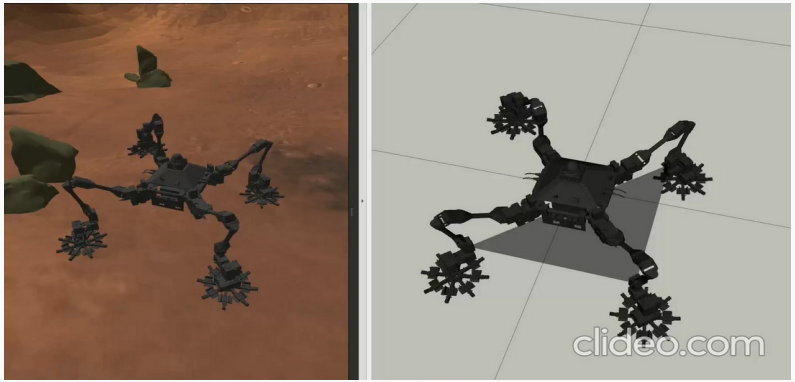
Main assumption: flat terrain

⬇

Stability of legged robot: **Support polygon**

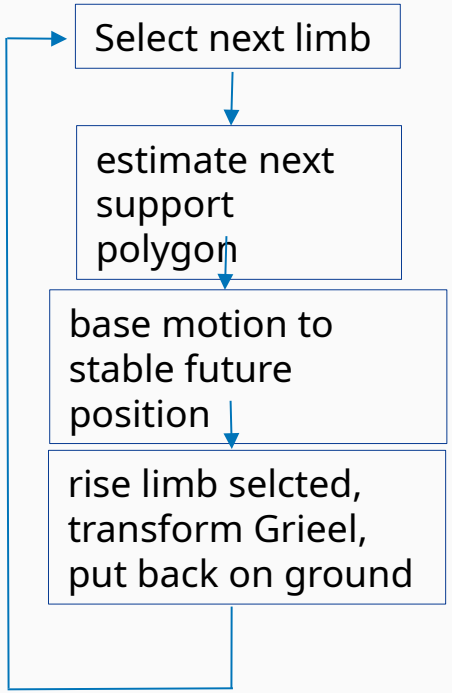


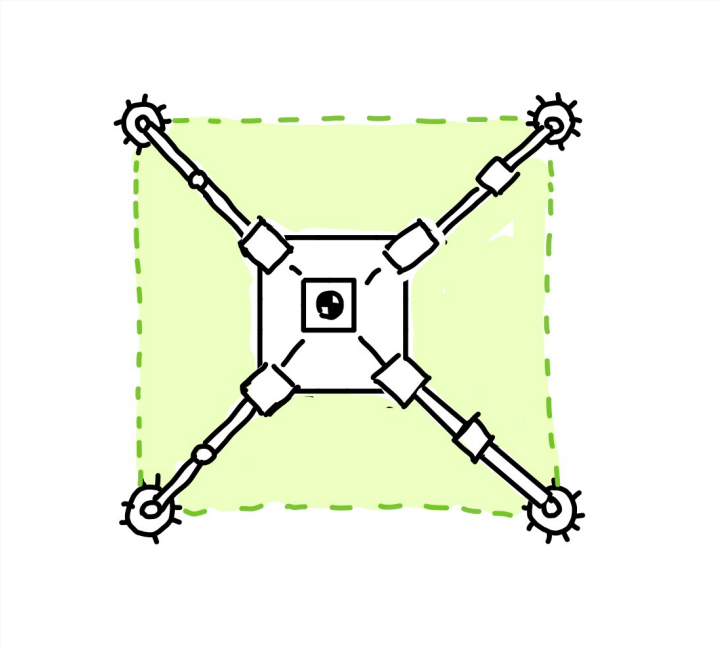
Unstable



Smooth transition Algorithm

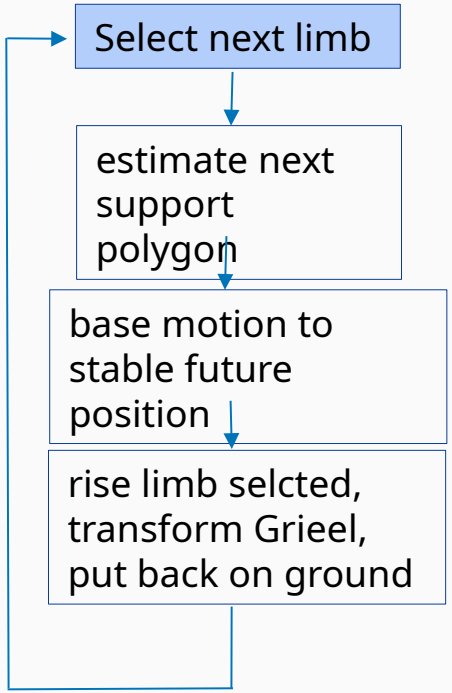
The SPACE ROBOTICS LAB

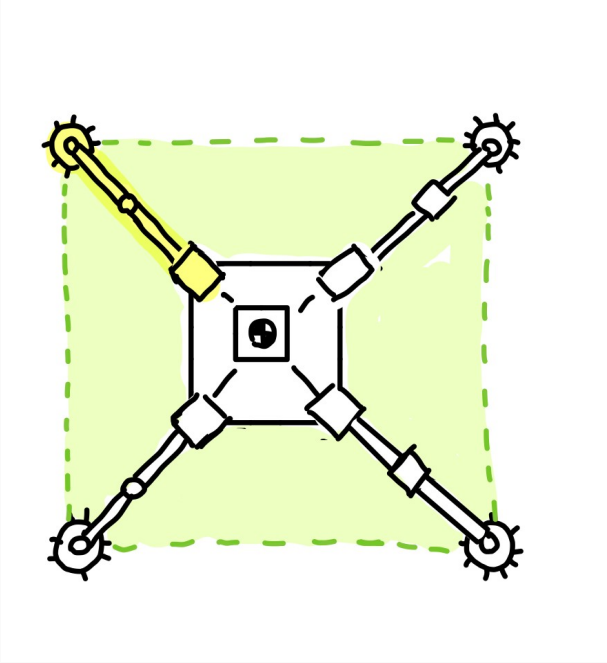




Smooth transition Algorithm

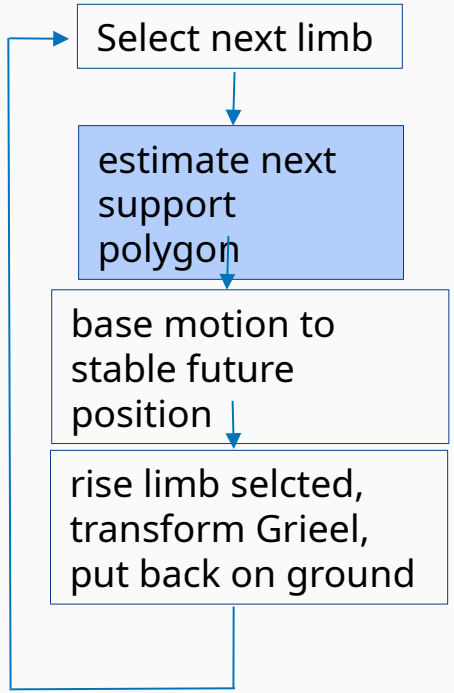
The SPACE ROBOTICS LAB

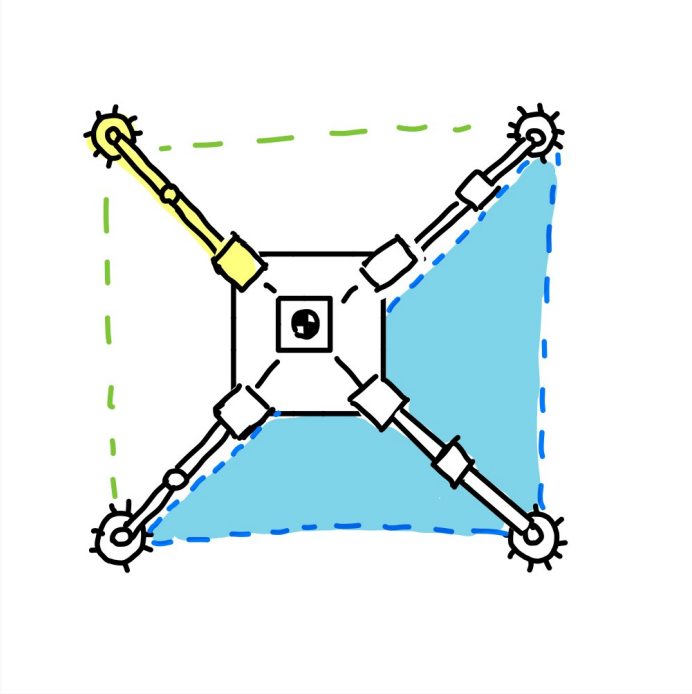




Smooth transition Algorithm

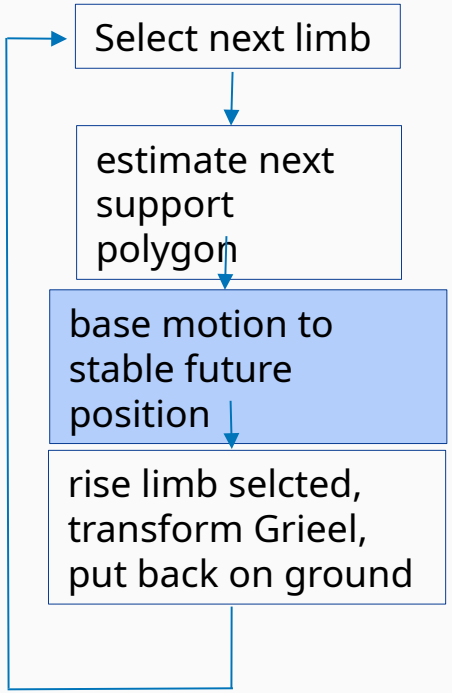
The SPACE ROBOTICS LAB

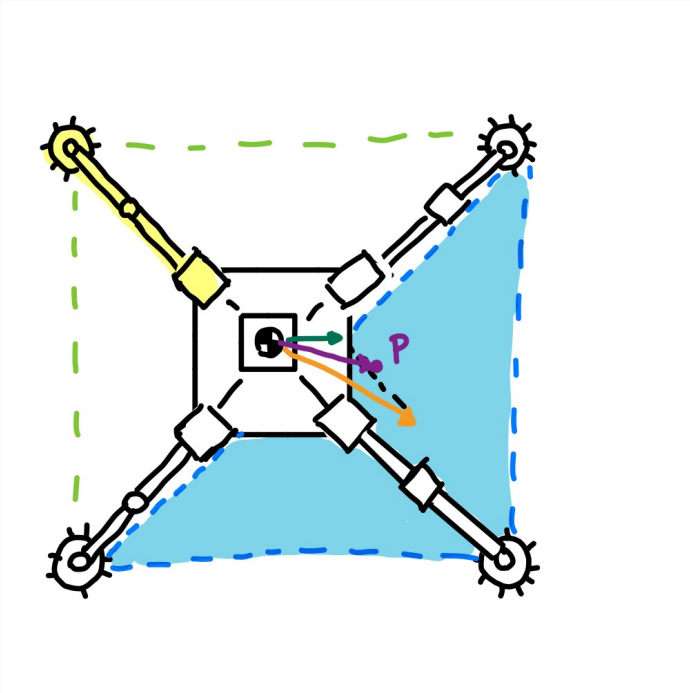




Smooth transition Algorithm

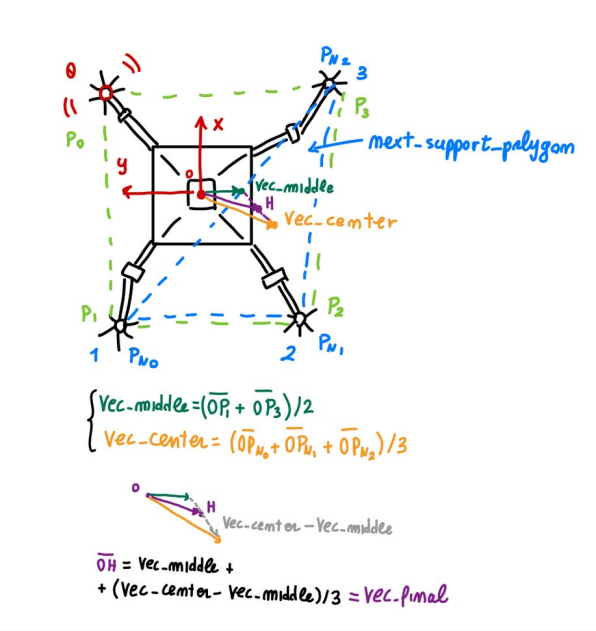
The SPACE ROBOTICS LAB





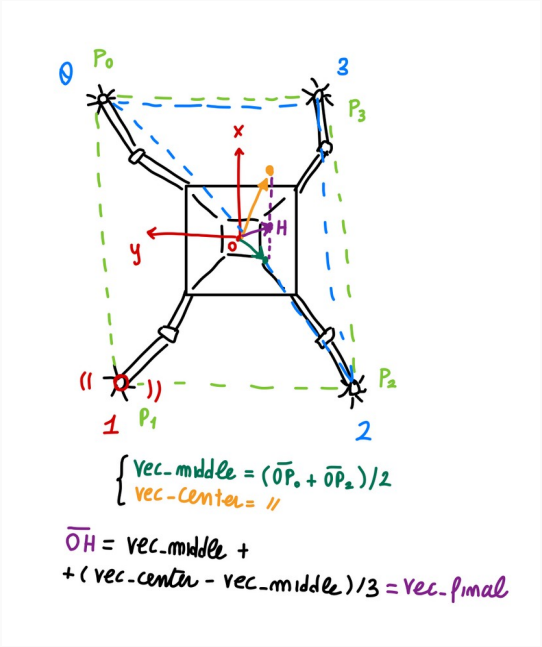
Base motion vector

limb_id = 0



Symmetric for limb_id = 2

limb_id = 1



Symmetric for limb_id = 3

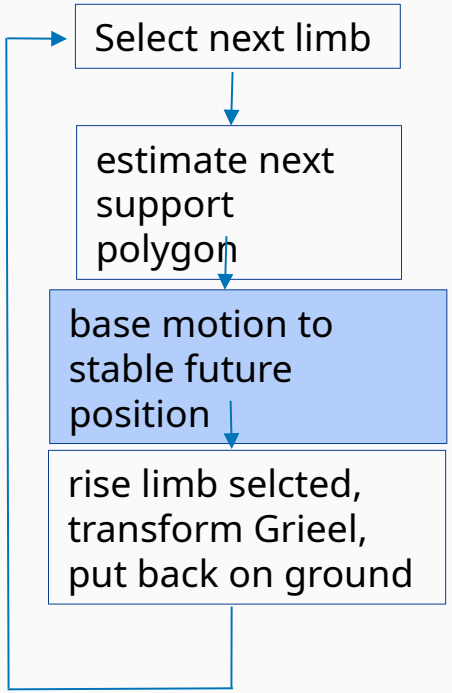
vec_middle := base to medium point of next_support_polygon's edge closer to the base

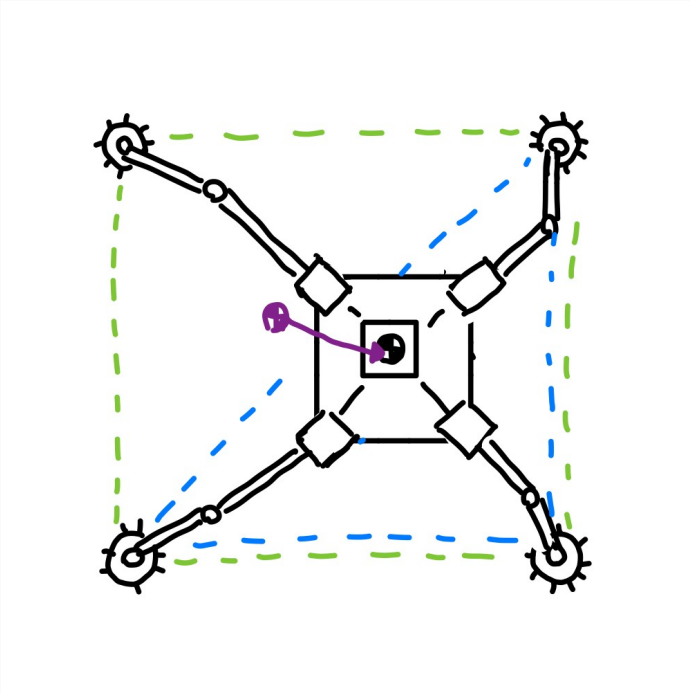
vec_center := base to center of next_support_polygon

vec_final := final base motion task to reach a stable position for the next limb raise

Smooth transition Algorithm

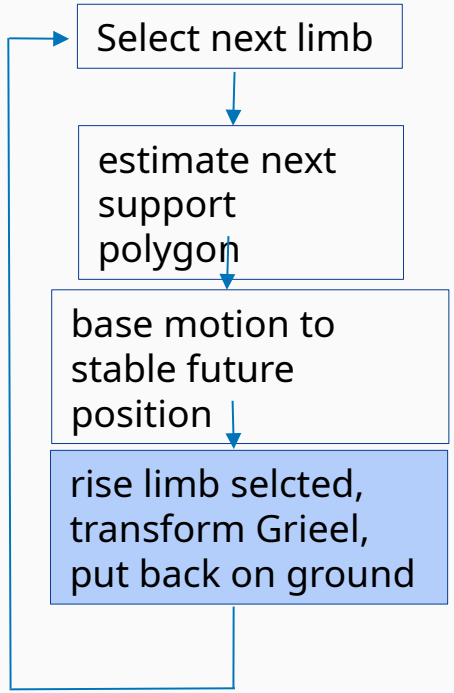
The SPACE ROBOTICS LAB

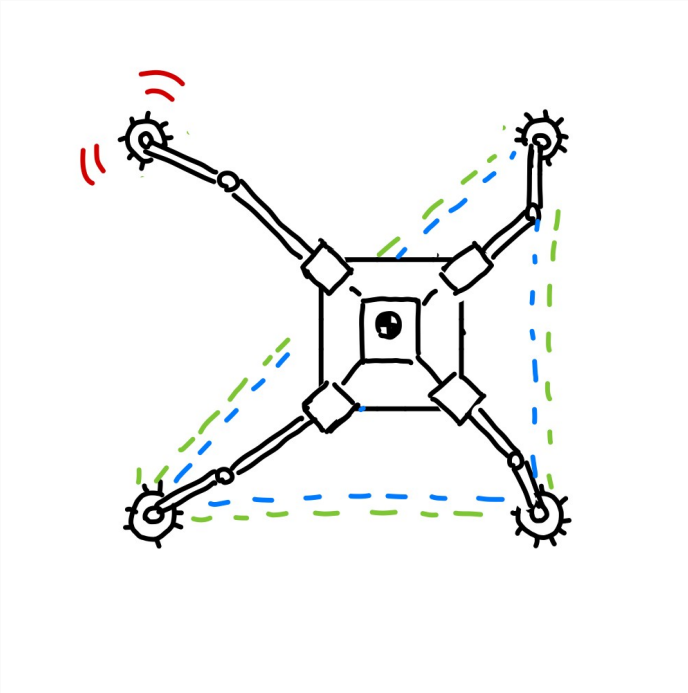




Smooth transition Algorithm

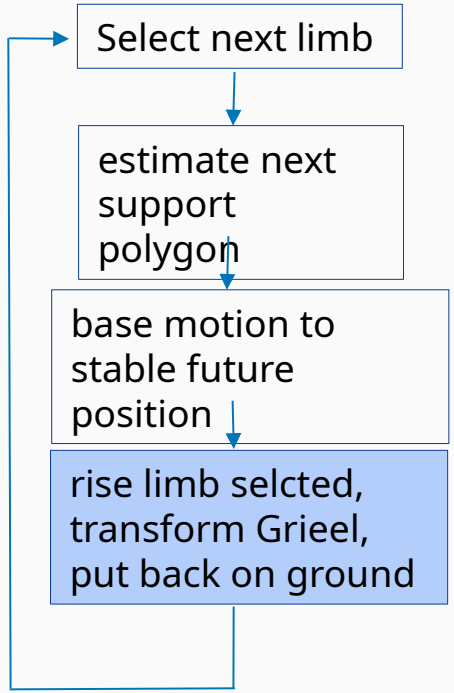
The SPACE ROBOTICS LAB

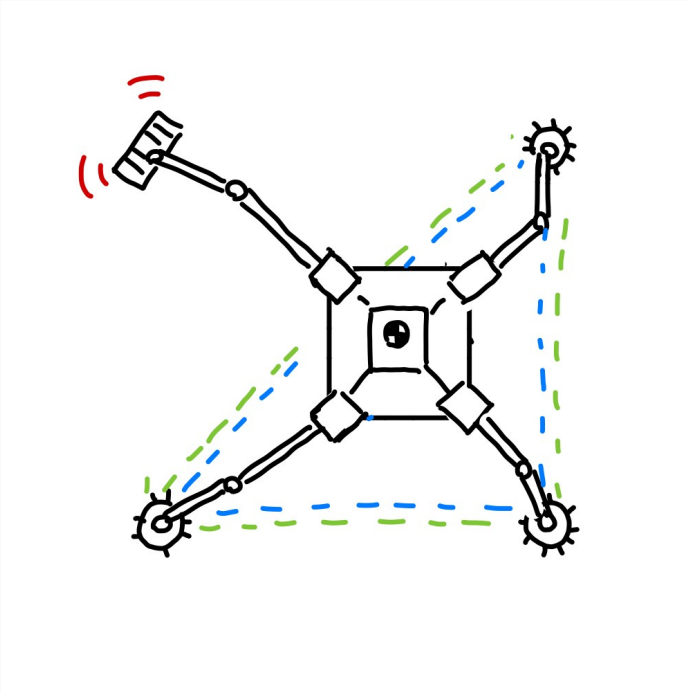




Smooth transition Algorithm

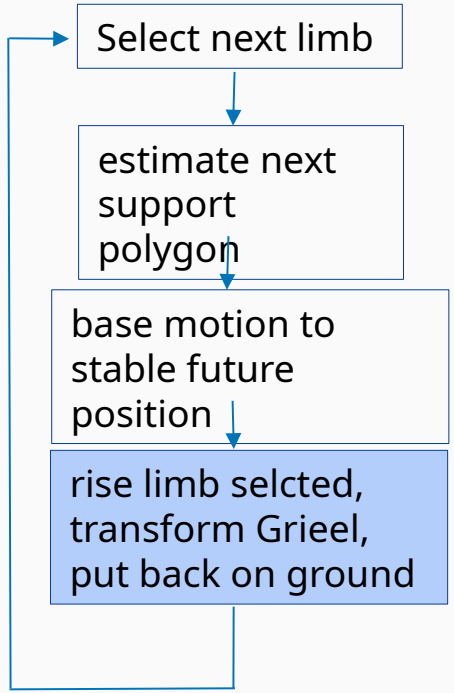
The SPACE ROBOTICS LAB

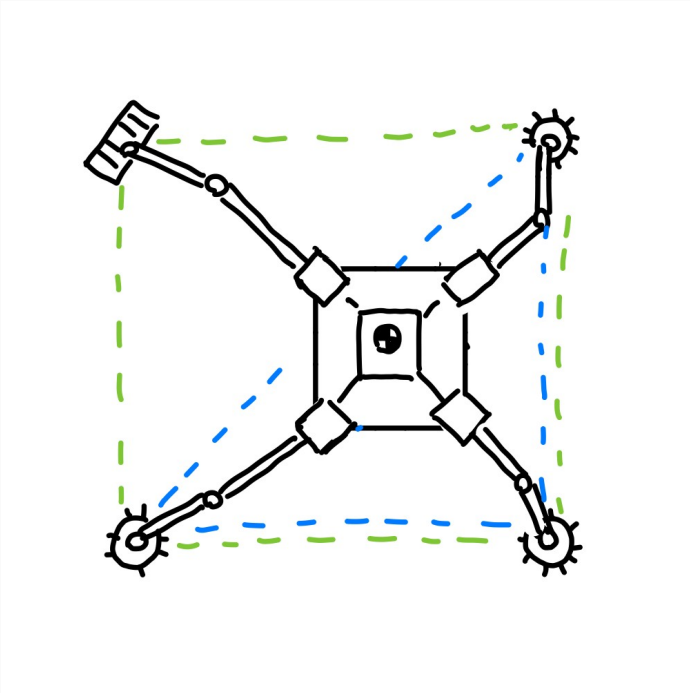




Smooth transition Algorithm

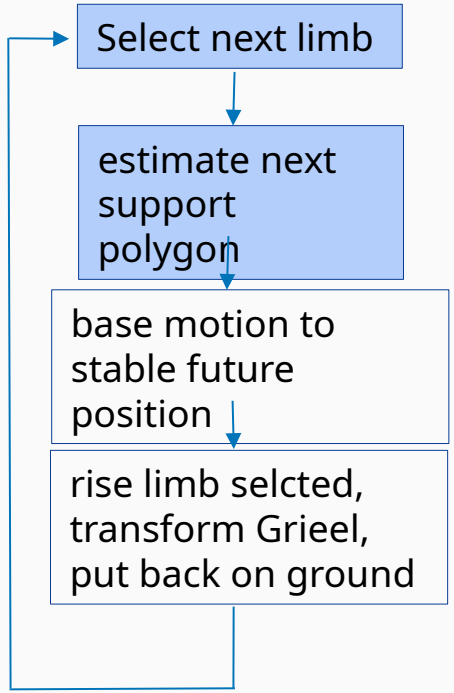
The SPACE ROBOTICS LAB

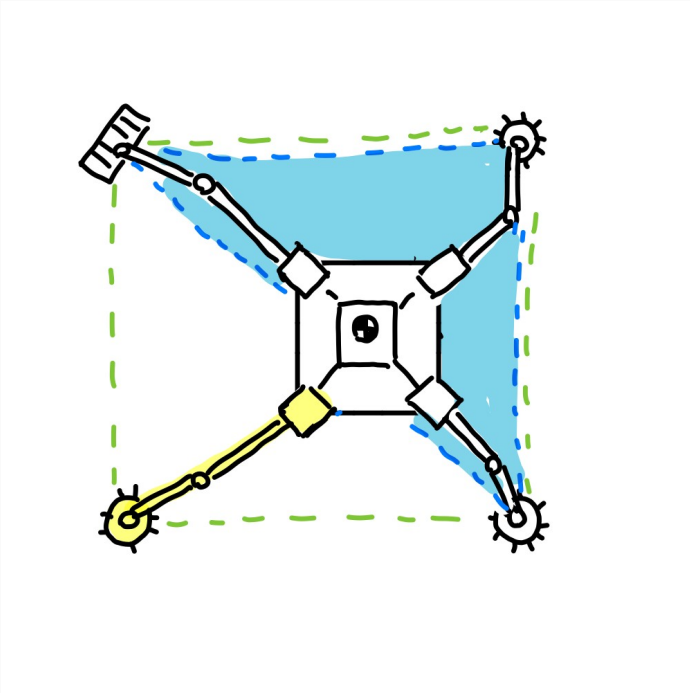




Smooth transition Algorithm

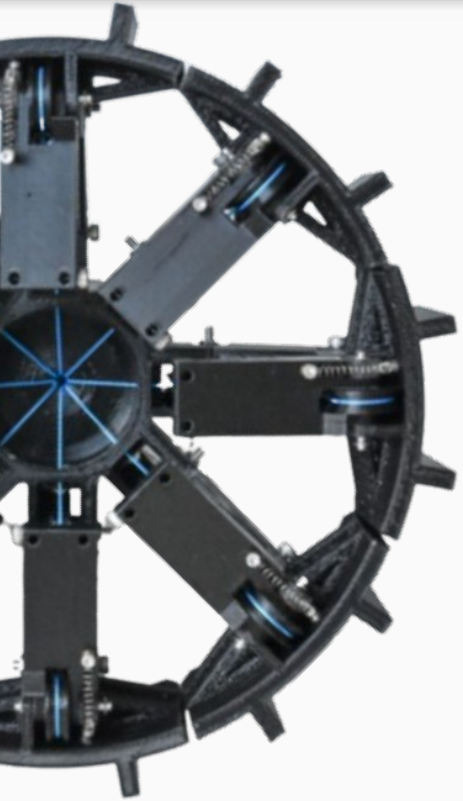
The SPACE ROBOTICS LAB





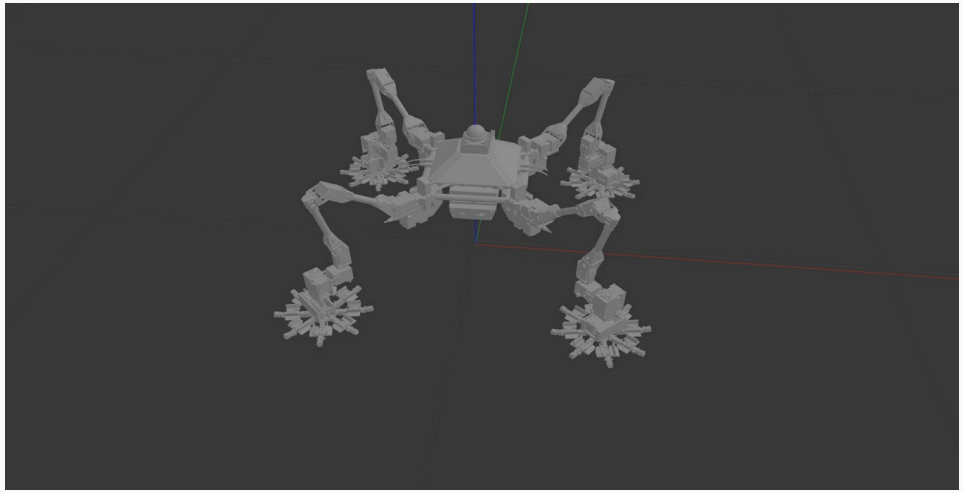
AGENDA

The SPACE ROBOTICS LAB



- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Grieel Joint Actuation



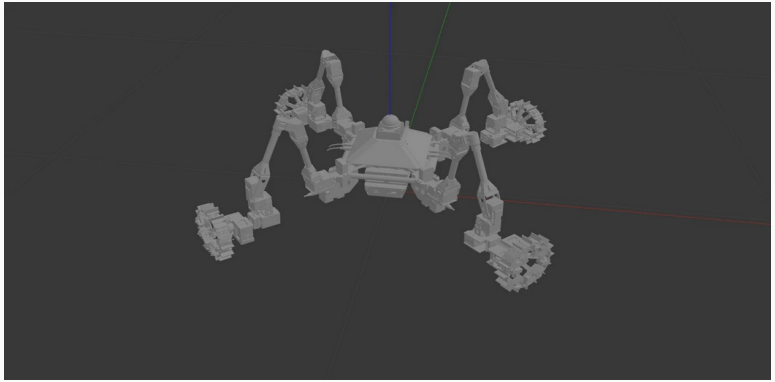
- Gazebo parameter tuned for reliable phisics
- Joints PID tuning for stable motion
- SW updated for GRIEEL joints

Stable Transition Sequence

The SPACE ROBOTICS LAB

Gripper Mode

Wheel Mode



2x

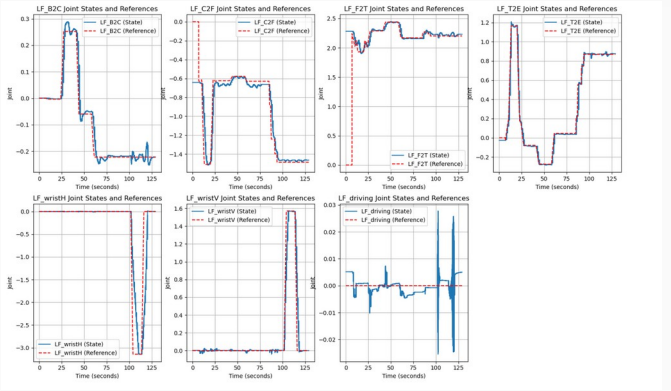
AGENDA

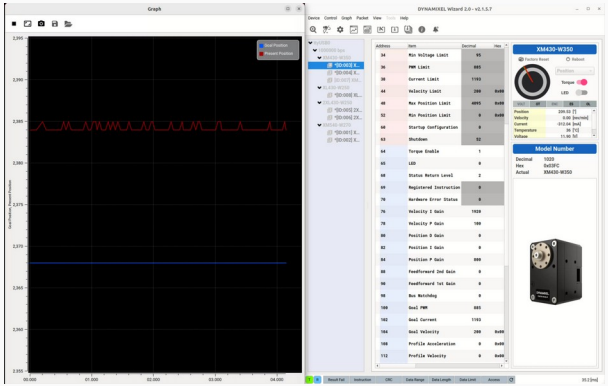
- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Gazebo & Dynamixel PID Tuning

The SPACE ROBOTICS LAB

- Trial and error PID tuning
- Keep track of controller performance in a table
- Dynamixel re-tuning in Dynamixel wizard





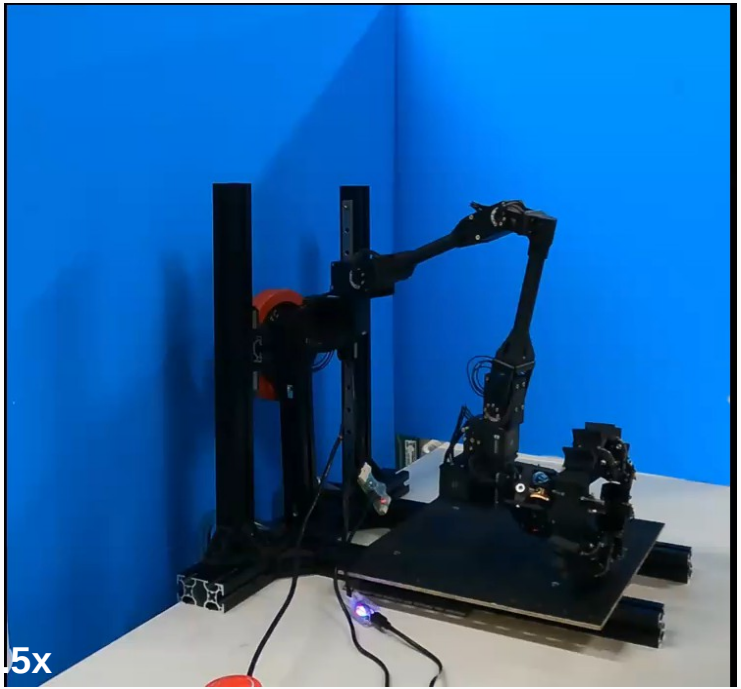
JOINT	Kp	Ki	Kd	Comments on performances
B2C	65.0	0.01	1.2	Satisfactory,Some additional over and undershoot introduced by wrist gains, but negligible
C2F	90.0	0.1	2.0	Satisfactory, small steady state error maybe caused by incoherent inverse kinematic solution
F2T	55.0	0.01	1.4	Satisfactory, small tracking error
T2E	100.0	0.0	0.0	Satisfactory
wristH	120.0	0.001	0.05	Satisfactory
wrsitV	120.0	0.0	0.01	Satisfactory
driving	80.0	0.0	0.0	Satisfactory, just small oscillations when W2G transition, maybe due to kinematic singularity, but negligible in simulation.

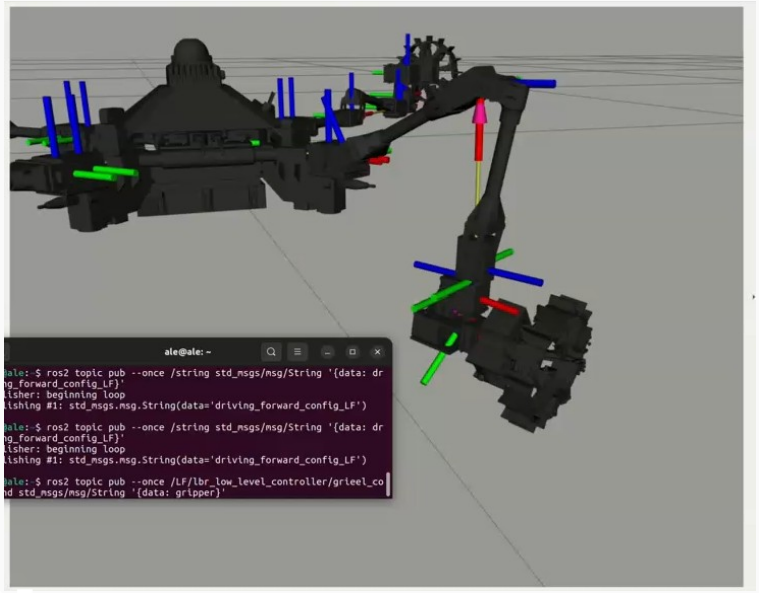
AGENDA

- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Single Limb Test

The SPACE ROBOTICS LAB

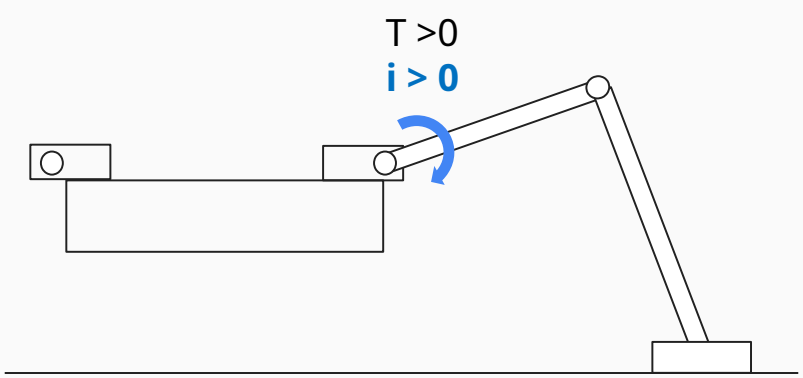




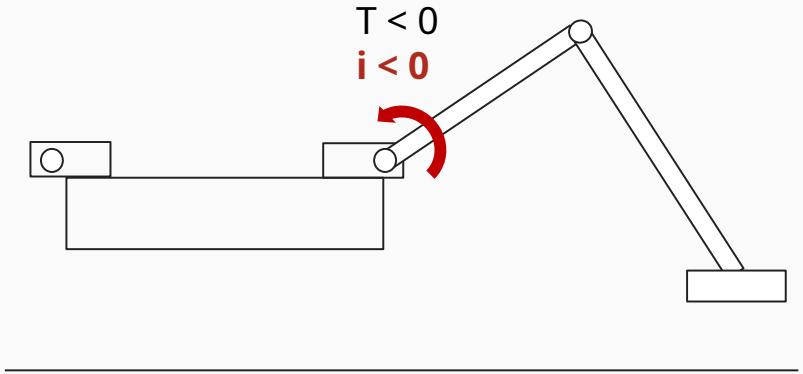
Contact sensor emulation

The SPACE ROBOTICS LAB

Lack of contact sensors in limb feet.

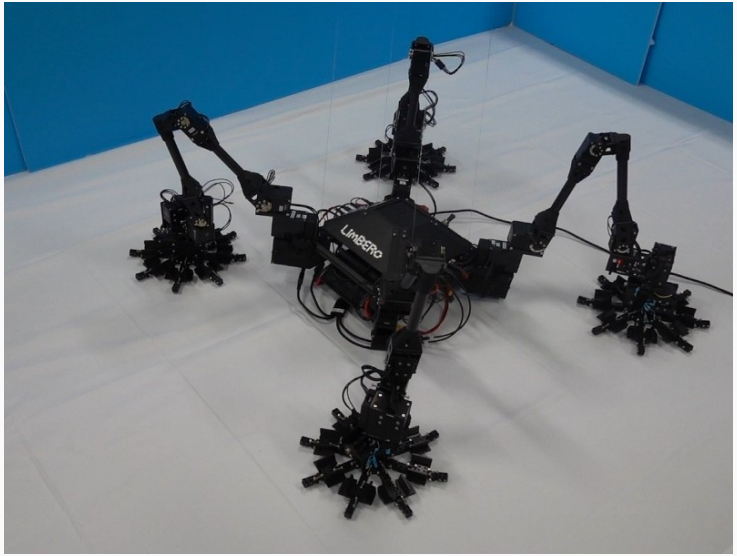


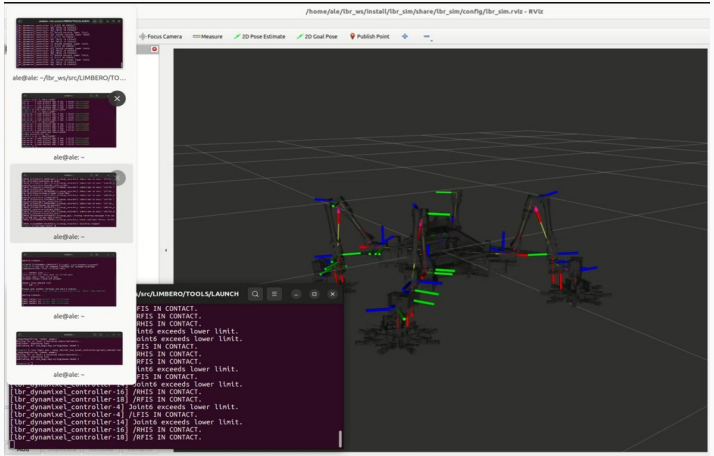
Limb in contact



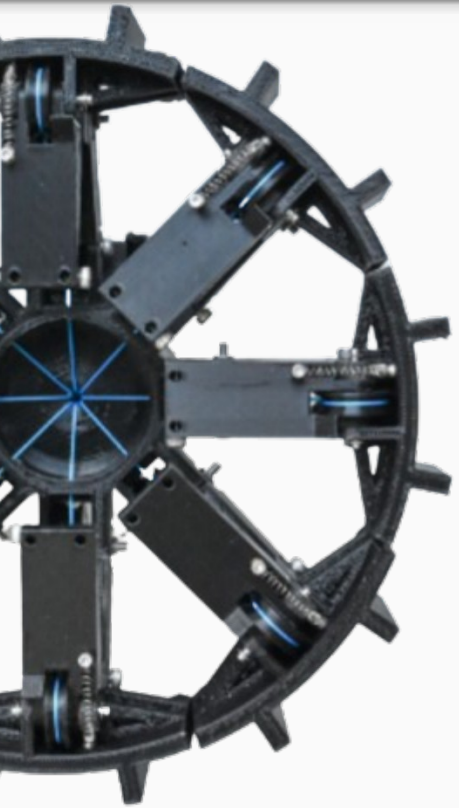
Limb not in contact

LIMBERO + GRIEEL Test





AGENDA



- INTRODUCTION
- SOFTWARE
- ALGORITHM
- SIMULATION
- CONTROL & TUNING
- EXPERIMENT
- CONCLUSIONS

Next Step

The SPACE ROBOTICS LAB

- LIMBERO+GRIEEL algorithm test with real sensors
- Different simulator for end-effector run time update
- Improve legged robot HW
- Test smooth locomotion transition
- Use sensors for optimal limb sequence and trajectory
- Implement advanced flexible locomotion

Acknowledgements

The SPACE ROBOTICS LAB

Thanks to all SRL team members.
To Naoki and Takada for late work and great help during experiment.

To professor Yoshida, Uno, Santra
For your feedback and help.

And to all of my friends here, that made this experience memorable.






Reference

- [1] NASA rovers' missions: Spirit and Opportunity (2004), Curiosity (2012), Perseverance (2022), CADRE (2024, future project)
- [2] Kentaro Uno, "Autonomous Limbed Climbing Robots for challenging Terrain Exploration", pp. 2-13, 2021
- [3] Shigeo Hirose et all. "Quadruped walking robots at Tokyo institute of technology, design analysis and gait control methods", 2009
- [4] Warley Francisco Rocha Ribeiro, "Reaction-aware robotic locomotion in microgravity", pp.34-37, 2023