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Space Robotics: The Frontiers of Exploration

CSIRO Space and Astronomy
Co-learnium Talk Series

Dr. Shreya Santra
Assistant Professor
Department of Aerospace Engineering
Tohoku University, Japan

AGENDA

- Introduction to Space Robotics
- Research at SRL Tohoku University
- Closing Remarks

History of Space Robotics

Lunakhod on Moon ©USSR

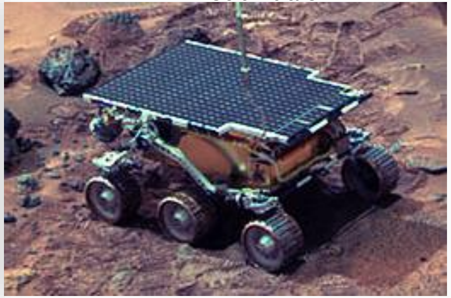
- Apollo landings with Moon buggy in the 1970s
- Lunakhod 1 and 2 the first rovers on another celestial surface (1970,1973) and travelled several kilometers
- Viking 1 and 2 landers had a robotic arm for soil sampling and in-situ analysis of the Martian surface
- Robotic arms on the space shuttle and space stations

ROTEX Arm onboard STS Columbia ©DLR

Apollo Missions ©NASA

Viking on Mars ©NASA

Venera on Venus ©USSR



Sojourner on Mars ©NASA

1960s 1970s 1980s 1990s

Application of Space Robotics

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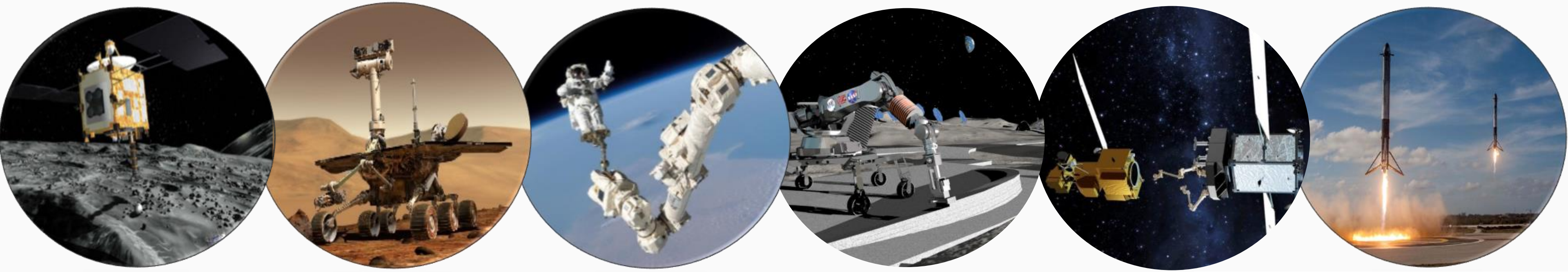
Scientific and Commercial Exploration

Survey of planetary surface

Assembly and Construction

Service and Maintenance

Robotic Landings



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Categories of Space Robots

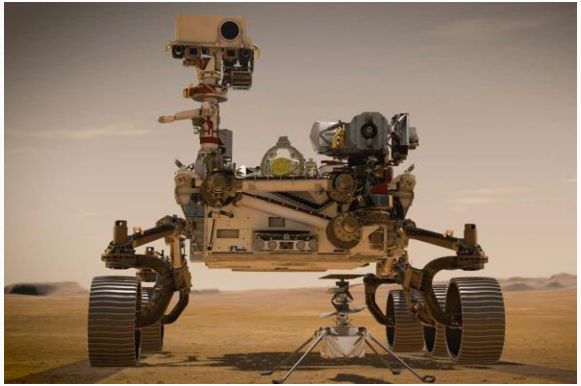
Orbital Robotics

- Orbital Operations and Services
- Space Debris Removal
- Microgravity Research

Planetary Robotics

- Probes for Scientific Exploration
- Precursors of future human expedition to remote celestial bodies

Canadarm ©CSA



Perseverance rover & Ingenuity quadcopter ©NASA

Challenges of Space Robotics

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Efficient Robot Designs	Mobility in different terrains	Localization and Mapping	Guidance and Navigation
Motion Planning and Control	Inter-agent Communication	Autonomous Capabilities	Swarm & Modularity
In-situ Resource Manufacturing and Utilization	Remote Operations	Testing and Qualifications	Mass and Power Limitations

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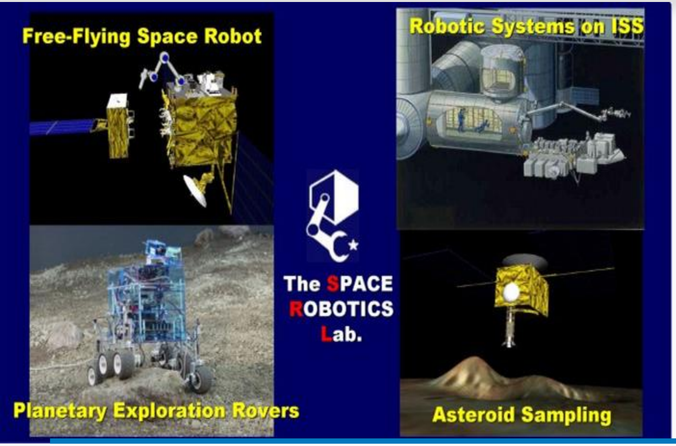
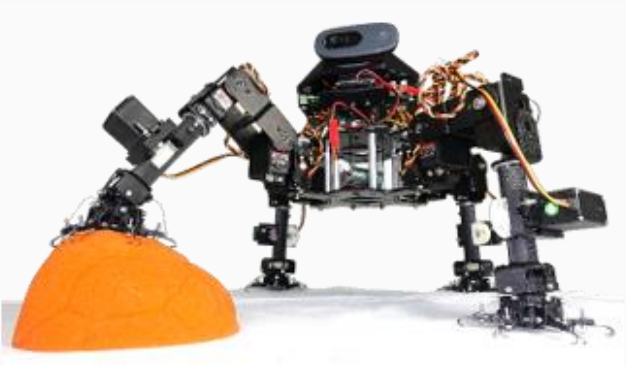
Space Robotics Laboratory (SRL)

Directed by Prof. Kazuya Yoshida



All Image credits ©SRL

Research Teams

- Orbital Team
- Limbed Team
- Terramechanics Team
- Rover Team
- Moonshot Team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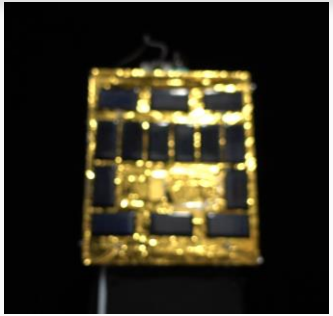
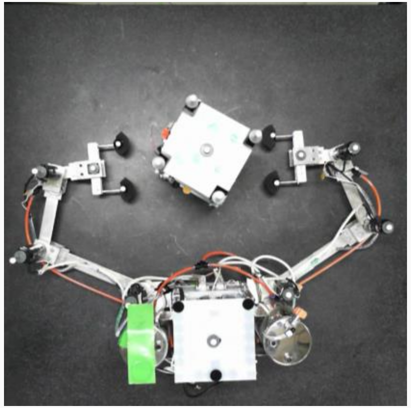
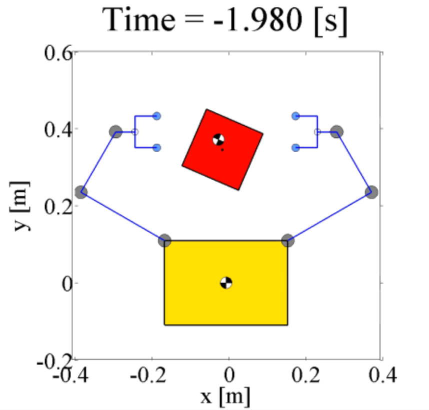


Structure from Motion (SfM)

Cage-based Target Capturing ©SRL





Orbital Robotics Research

- Machine vision to estimate pose of debris
- Robot control in microgravity
- Object Tracking and Capture mechanisms
- Mobility mechanisms on minor bodies
- Sample collection on asteroids

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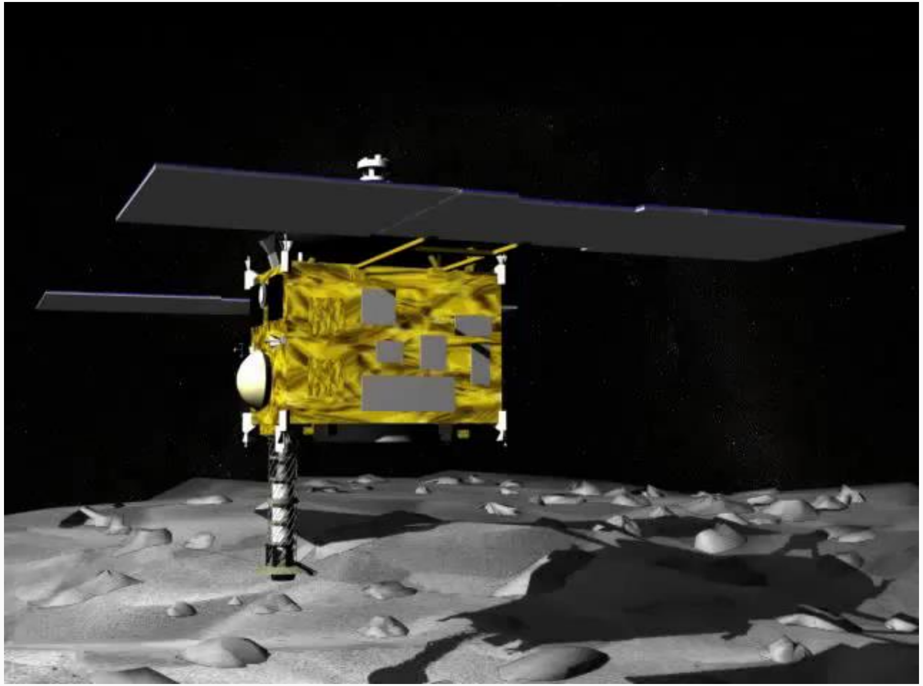
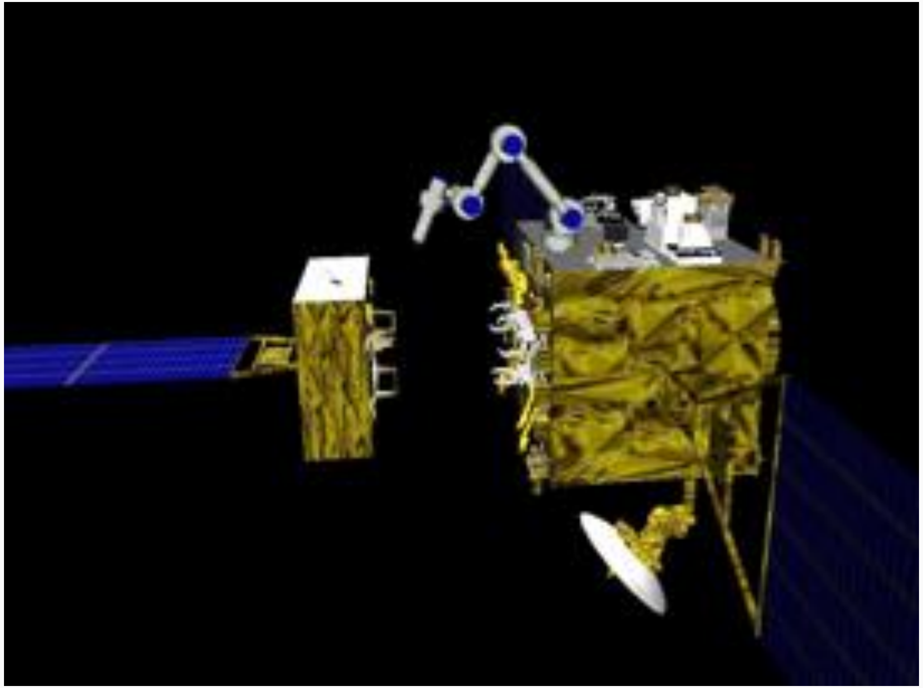
Hayabusa1 sample collection ©SRL



Orbital manipulator ©SRL



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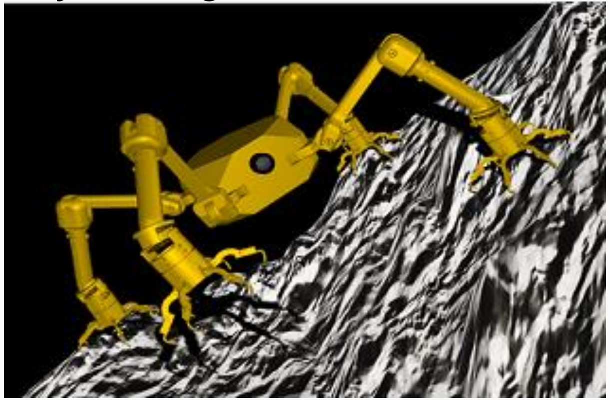
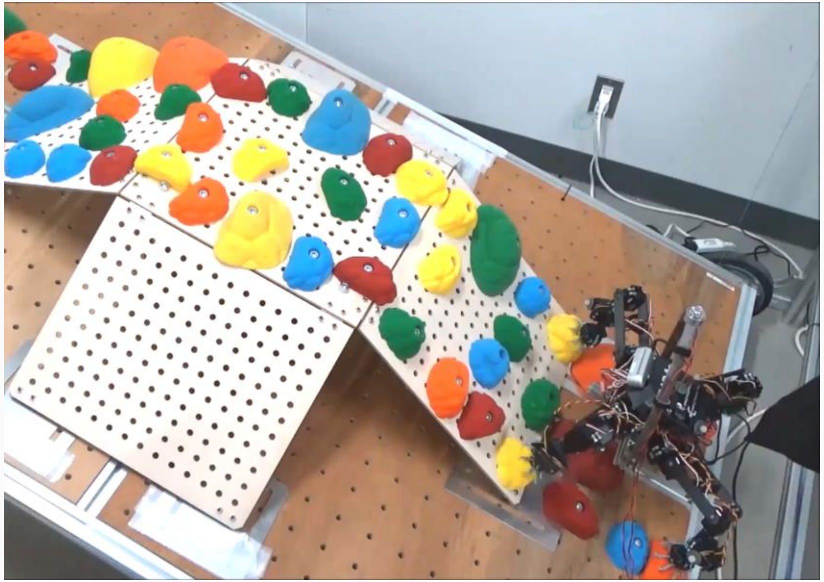
Mobile Limbed Robotics Research

- Dynamic analysis and design of Limbed Robots for challenging terrains and onboard the ISS
- Perception, Planning and Control
- Grasping and Mobility
- Gait patterns inspired by bio-organisms





HubRobo on test bed ©SRL

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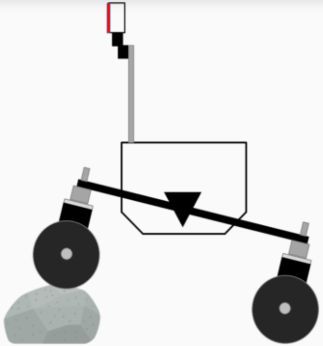
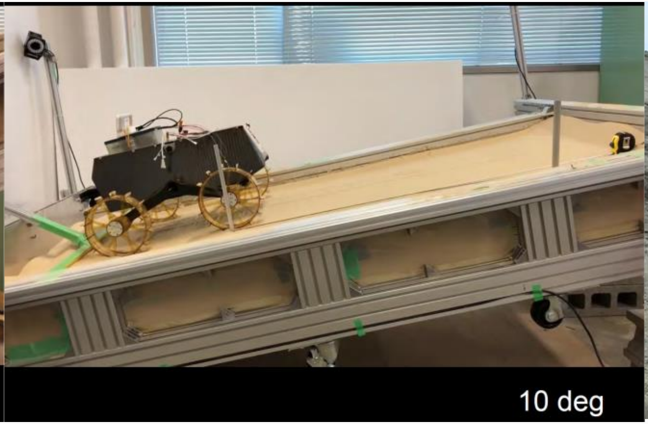
Terramechanics Research

- Safe mobility for robots on different surfaces
- Understanding driving performance and stability evaluation
- Designing of wheels and suspension system





Rover locomotion tests ©SRL

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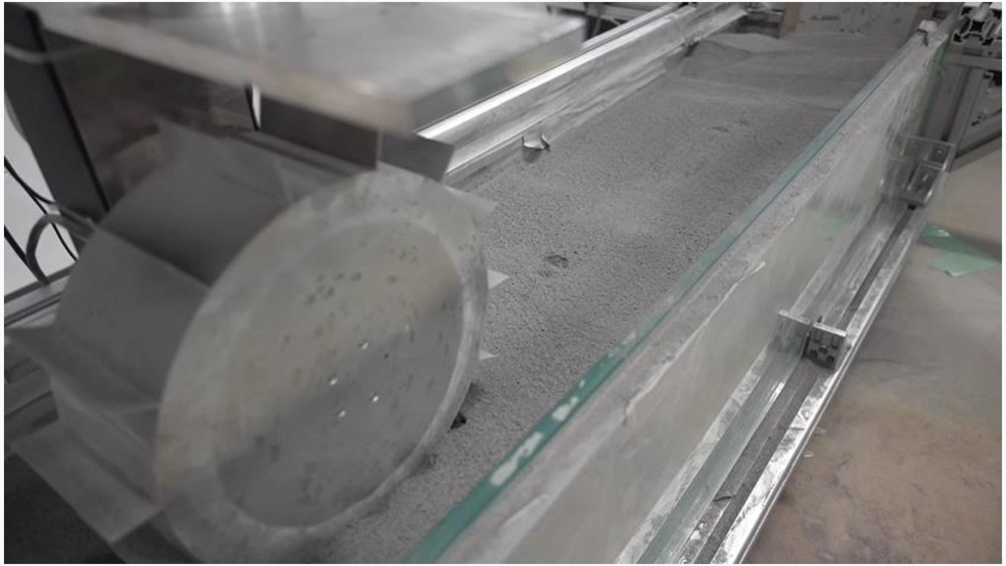
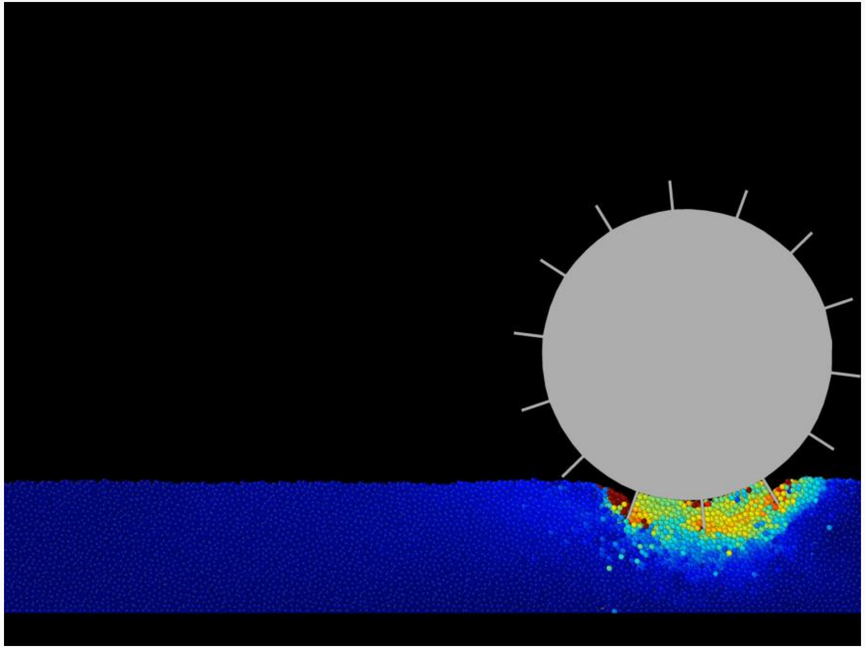
Single wheel locomotion performance



Lunar simulant Testbed ©SRL



Discrete Element Method Simulation ©SRL

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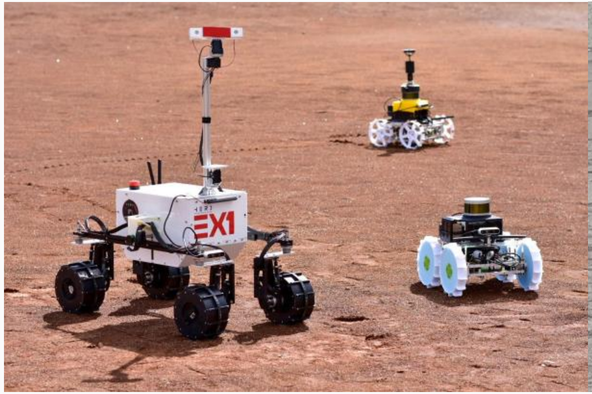
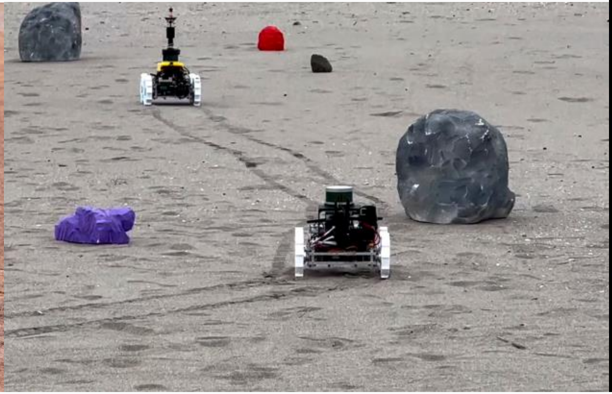
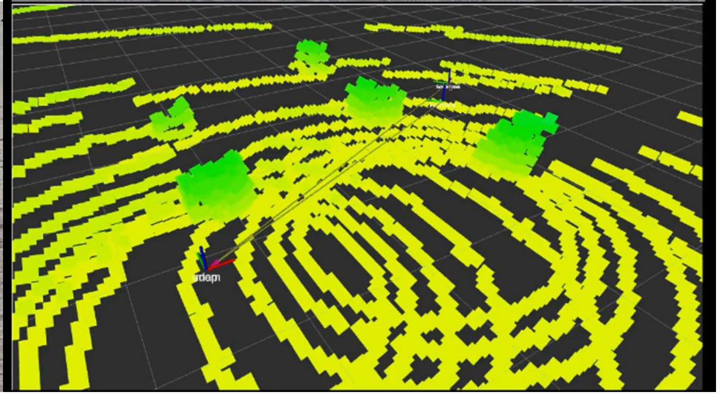
Rover Research Topics

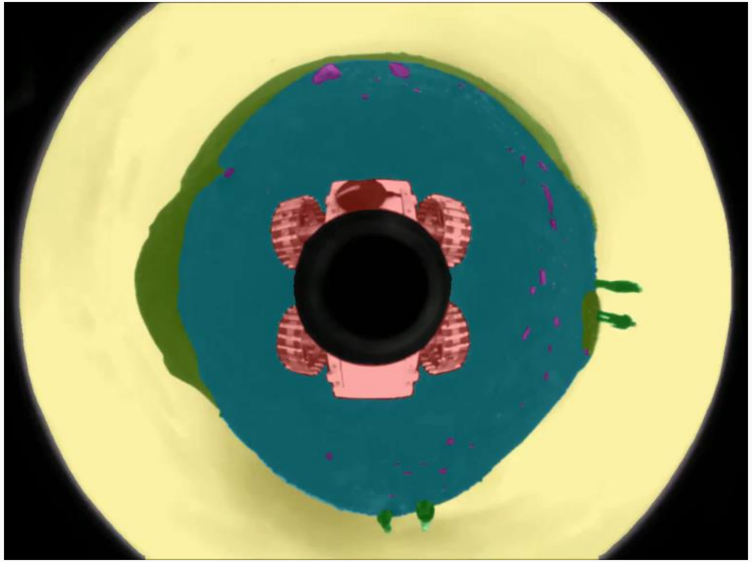
- Perception and Path Planning
- AI for rover localization and motion planning
- Multi-robot coordination strategies
- Sim-to-real Hierarchical Planning



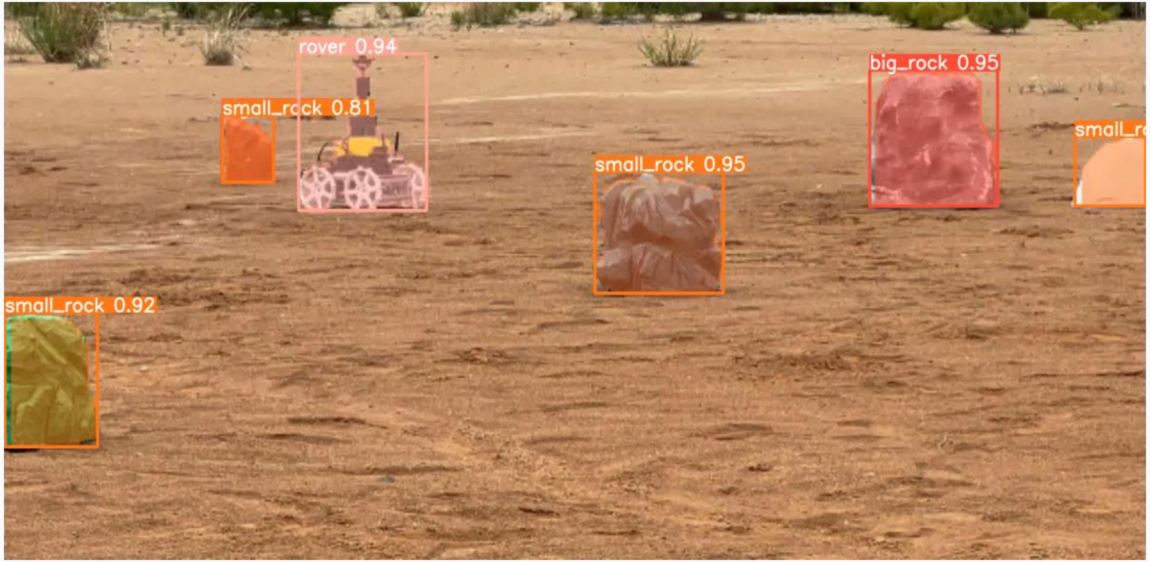




Semantic segmentation using Omnicamera



Instance segmentation using Stereo RGBD camera



Outdoor experiments ©SRL

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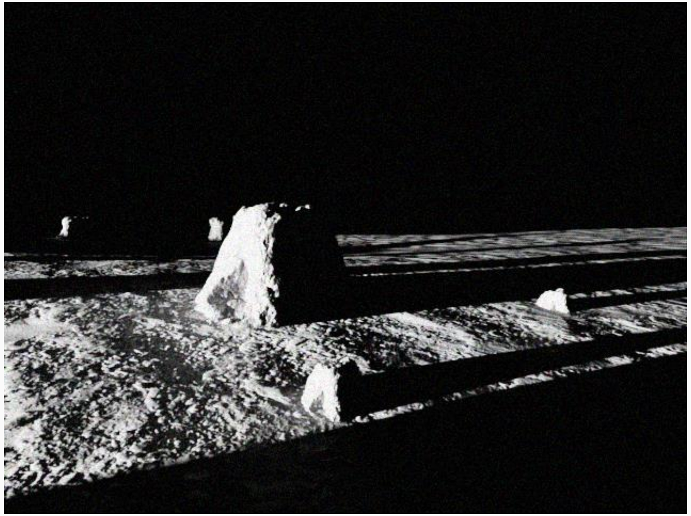
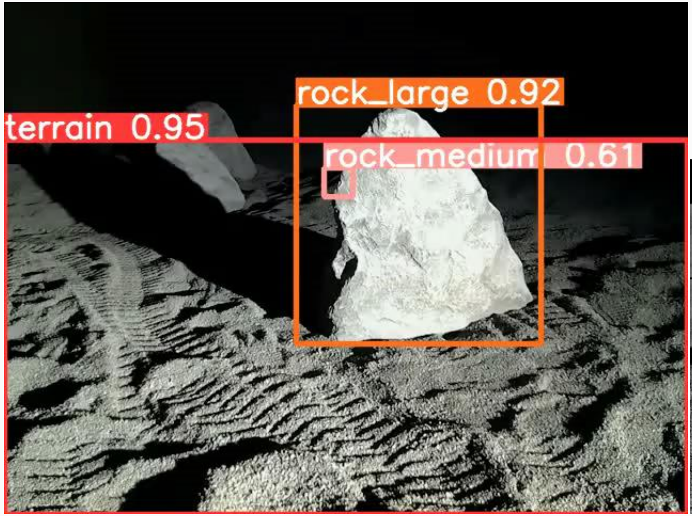
Photorealistic Simulator for Sim-to-Real Training



Synthetically generated training data ©SRL



Validation on real world experimental data from lunar simulant testbed ©SRL-SpaceR Luxembourg

Robots on photorealistic simulator

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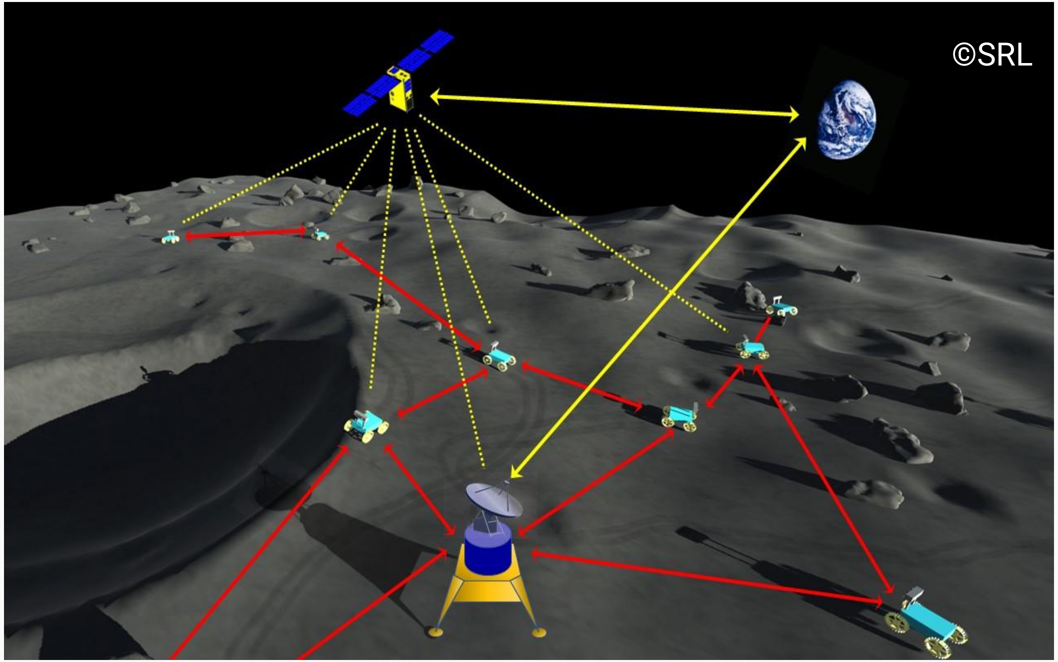
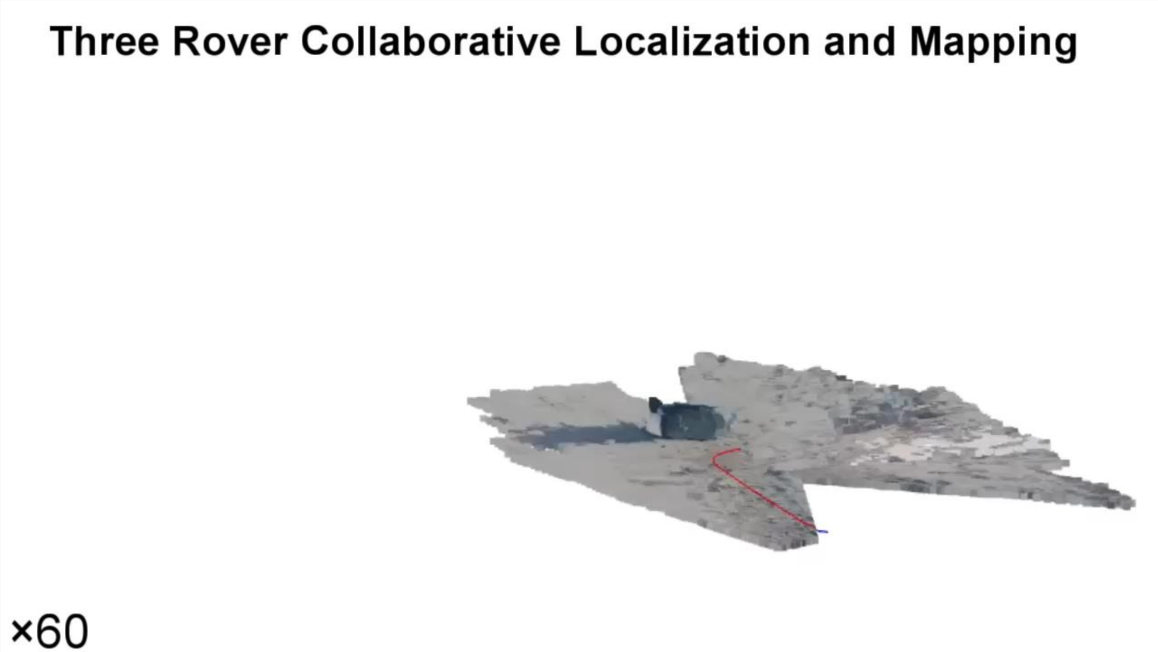
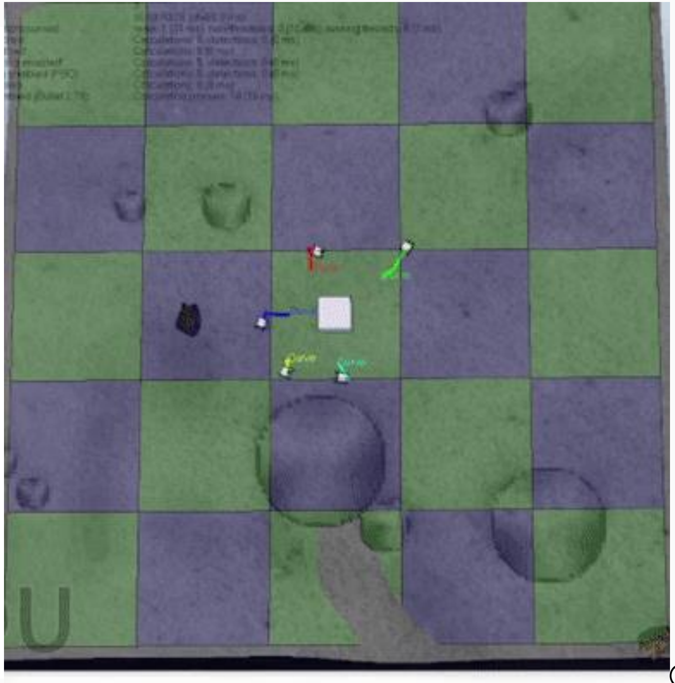
Heterogeneous Multi-Robot Systems for Planetary Exploration



- Main advantages of swarms: adaptability, robustness, and scalability.
- Redundant and low risk factor
- Modular, flexible and cost-effective

Swarm Exploration strategies: SLAM and Path Planning





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MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

Moonshot Goal 3

Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.

Self-evolving AI Robotic System for Lunar Exploration and Human Outpost Construction

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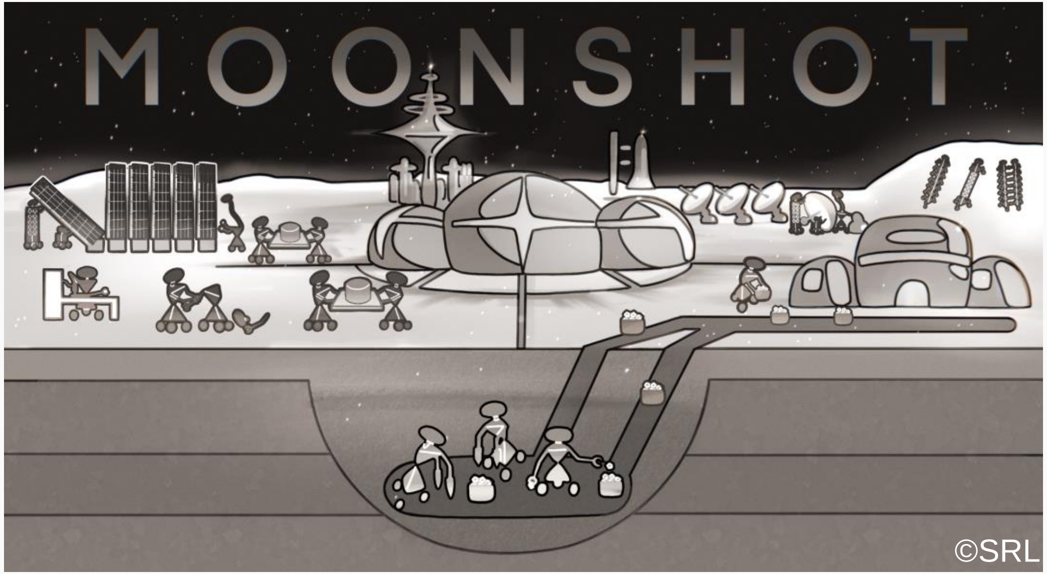
Key Ideas

- **Modular** and **Reconfigurable Heterogeneous** robotic systems (flexibility and adaptability to unknown environments and unpredictable situations)
- **Transferable AI System** for plug and play implementation (skill transfer)
- On-demand robot design, **On-site Fabrication** (ISRU and manufacturing)



Artist's illustrations of Self-evolving AI Robot System for Lunar Exploration and Human Outpost Construction

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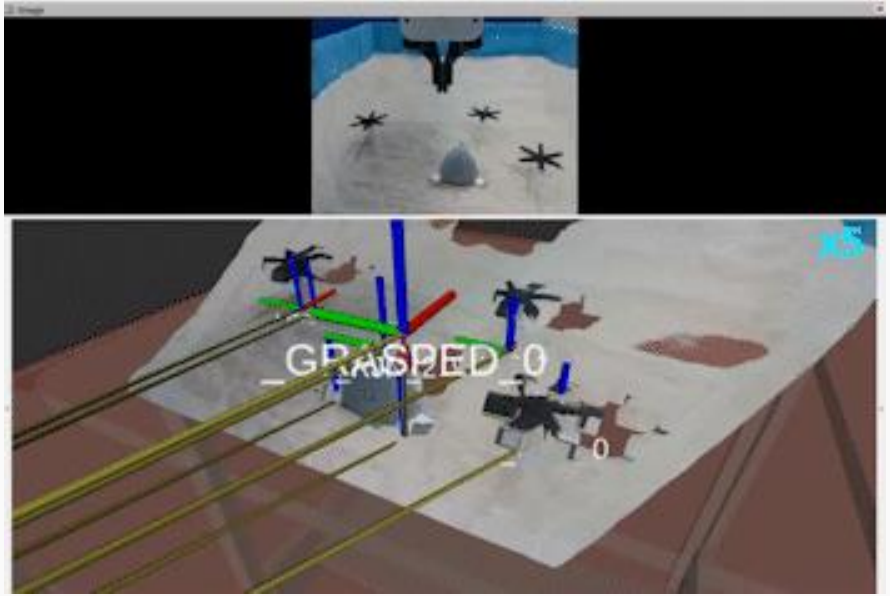
Grasping and Manipulation Tasks



Object detection and Grasping by articulated manipulator in lunar like conditions ©SRL

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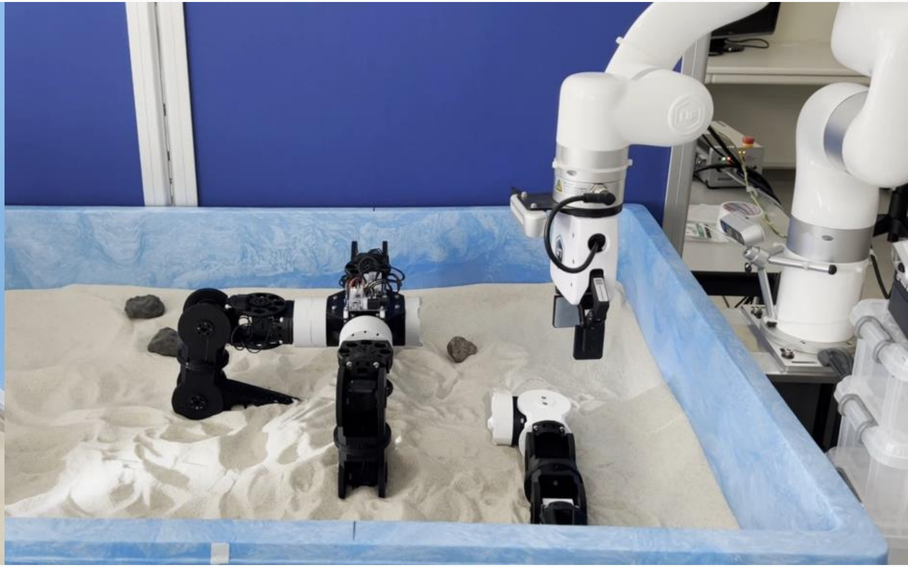
Modular Robot Research

Modular robot Assembly and Gait Planning ©SRL

Future of Space Robotics

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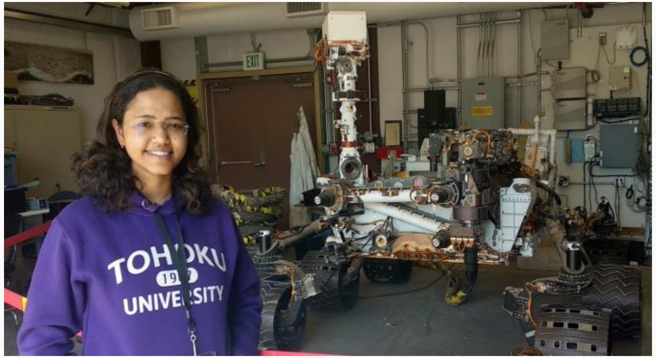
- Space Robots is a rapidly growing field with several challenges to address
- Sustainable space dreams can be achieved by incorporating multiple robotic missions
- Robotics and AI is an interesting potential both for academia and commercial newspace companies

THANK YOU!



WEBSITE

shreya.santra@tohoku.ac.jp