Development of URCHIN: An Autonomous Multi-Agent Framework for Extraterrestrial Exploration

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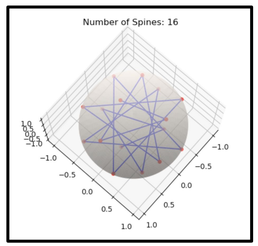
Background

Developing small, autonomous rovers to assist humans and larger rovers is important for enhancing the outcomes of space exploration missions, Figure 1. Current swarm vehicle concepts are designed for deployment in one specific environment which limits the reusability of a rover from one environment to another. This project contributes to the development of a coordinated, multi-agent system of sample collection rovers capable of traversing diverse terrain types. The research objective focuses to validate a rover design concept that approaches to solve the limitations of its counterparts while innovating upon a novel, telescoping mechanism for legged locomotion and sample collection.

Progress



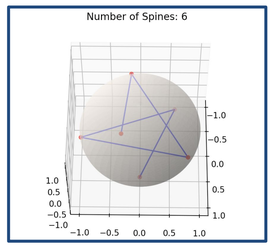
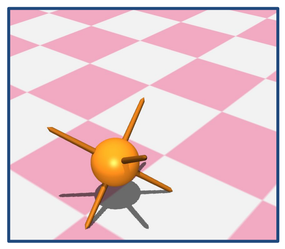


Fig. 3.
Images to the left show outputs of a function to populate some N number of legs used to determine the point distribution of legs around the center body.



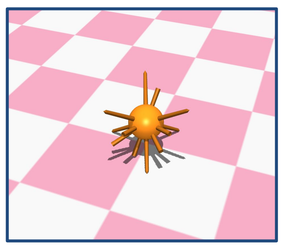


Fig. 4.
Images to the right show the URCHIN model in the sim environment. (a) Model with 6 legs. (b) Model with 12 Legs.

Methodology

Three planetary bodies within our reachable solar system were chosen to be regions of interests in our study, to include Earth's Moon, Mars, and Europa (a moon of Jupiter). Each body is home to either current, Figure 2, or planned extraterrestrial exploration missions offering a diverse set of terrain types- ranging from rocky and dusty, to icy.

Validating the versatility of the URCHIN design required analyzing the rover's unique means for locomotion across the different terrestrial conditions offered. Terrain and environmental characteristics of each region of interest were catalogued, Table 1, and used as parameters in a simulation environment developed using the MuJoCo physics engine and Python. Some of the characteristics included the gravitational force exerted on the agent, the average elevation grade (slope) of the region, and the unique texture of the surface. A desired outcome of the study is to determine the optimal number of legs, Figure 3-4, the vehicle needs for fault tolerance in the case of loss. Future simulations will provide data needed to improve upon the performance of the telescoping mechanism design for rover locomotion.

Table 1. Characteristics were collected to analyze the URCHIN's maneuverability in a simulated environment.

	Surface Terrain Data Collection Table		
PLANETARY BODY	Moon	Mars	Europa
REGION	South Pole	Jezero Crater Area	Conamara Chaos
COORDINATE REGION	89.66°S 129°E	77.44°N, 18.434 °E	9.7°N 272.7°W
g (m/s²)	1.62	3.721	1.315
TERRAIN CHARACTERISTICS	pocked, cratered	sand dunes, mudrock	icy, chaotic
SOIL CLASSIFICATION	glass, silica, regolith	dust, sand	silica rock
AVG GRADE (°)	11°	23.5°	< 15°

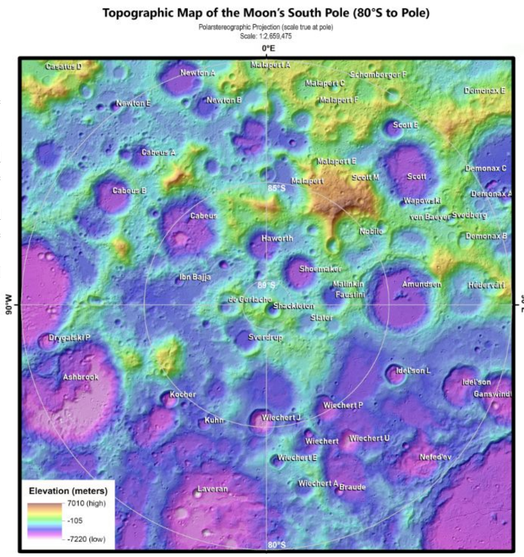


Fig. 2.
Topographic map of the Moon's South Pole, the proposed landing site of NASA's next manned mission to the Moon, Artemis III [1].

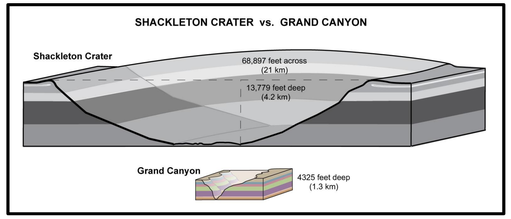


Fig. 1.
Cross section size comparison of Shackleton Crater to the Grand Canyon. Swarm systems can assist in areas too treacherous for humans and large rovers to explore [2].

Future Work

Further research will include modeling of reinforcement learning methods to derive a walking gait strategy for the agents then the development of algorithms for coordinating swarm behaviors and the allocation of tasks.

Acknowledgements

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References

[1] Lunar and Planetary Institute/CLSE
[2] Stopar J. and Meyer H. (2019) Topographic Map of the Moon's South Pole (80°S to Pole), Lunar and Planetary Institute Regional Planetary Image Facility, LPI Contribution 2169

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Research question

- Research question/motivation
- Research methods
- Obstacles faced/overcome
- Findings and progress thus far
- Acknowledgements

locations that current research is already developed or is home to current space exploration to be cost effective for multi-planetary missions.

The objective of this research is to validate and analyze the performance of URCHIN, an autonomous, multi-agent system of sample collection agents, designed to traverse a diverse set of extraterrestrial terrain types found within the reachable solar system.

Future Work

Further research will include modeling of reinforcement learning methods to derive a walking gait strategy for the agents then the development of algorithms for coordinating swarm behaviors and managing task allocation.