Mobility system for extreme terrains on the Moon for NASA's challenge

A capstone project report submitted in partial fulfillment of the requirement for the degree of

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ABSTRACT

The objective of this full project is to design and develop a novel mobility system to be applied on extreme terrains of the Moon for NASA's challenge, although in this report I will be only talking about the design part and how we came with it. First, we had to choose and focus on a type of potential mission that the rover using that mobility system would do. Once the mission was chosen, various ideas were presented regarding mobility systems and between those, we decided what type of system we would use by mixing different ideas from different proposals. It had to be something new and couldn't be common like for example wheels. For the selection of the system, we had to research and overcome the possible difficulties we would find on the extreme terrains of the moon, like magnetic dust, big slopes or extreme temperatures between many others. After various meetings and considering different approaches, we ended up choosing a mobility system that would work with soft robotics, a robot with octopus-like tentacles where the arms could be detached to inspect more surface that would act like snakes with different modules. We decided to call this robot the UC-Ebot.

INTRODUCTION

For this project we designed novel mobility system for use in off-world extreme lunar terrain applications for a challenge that NASA hosts. This challenge is called "NASA's Breakthrough, Innovative, and Game-changing (BIG) Idea Challenge", and for it, NASA asks engineering teams from different universities to develop some sort of new technologies. The one hosted this year, which is the one we worked on, is called "The 2022 big idea challenge: Extreme terrain access for mobility platforms" and the objective was to "Design, develop, and demonstrate robotic systems with alternative rover locomotion modalities for use in off-world extreme lunar terrain applications" [1].

To complete this project, we met various times and we also worked each one individually researching and thinking about possible ideas and alternatives for each next step required. We first started selecting the mission our rover would face, since depending on that, different kind of terrains could be found. We ended up choosing to explore lava tubes. Once we knew what we were exploring, we researched what kind of situations and terrains we would face in that environment, and accordingly, we thought about and brainstormed possible mobility systems. By discussing and combining various ideas, and after various meetings and exhaustive research, we ended up deciding to use soft robotics in an octopus-like rover with detachable arms that could explore independently like snakes.

METHODS

First thing we had to do, was to choose a potential mission to focus on since depending on the nature of said mission, different kind of terrains could be found. We could choose between four options NASA suggested or any other different one if had any different preferences. The four options suggested by NASA were the following ones:

⇒ Fluffy/high-porosity regolith expected at the lunar poles

⇒ Steep, rugged slopes (state of the art for a wheeled rover is ~30 degrees)

⇒ Uneven terrain with possible ice content at the bottom of deep-shadowed craters

⇒ Subterranean features, such as caves, lava tubes, and pits

After meeting and discussing options, we decided to focus on exploring the lunar lava tubes since it is a location yet to explore.

Once we decided what our mission would be, we had to research the environment to know what kind of terrain, situations and possible problems we could expect in there. The problem was that lava tubes are a quite unexplored place, so not much detailed information was available, because of that, we also had to research lava tubes on Earth, since they have some similarities.

These lava tubes were created from lava flowing through them when there was volcanic activity on the moon and they look like this from the space:

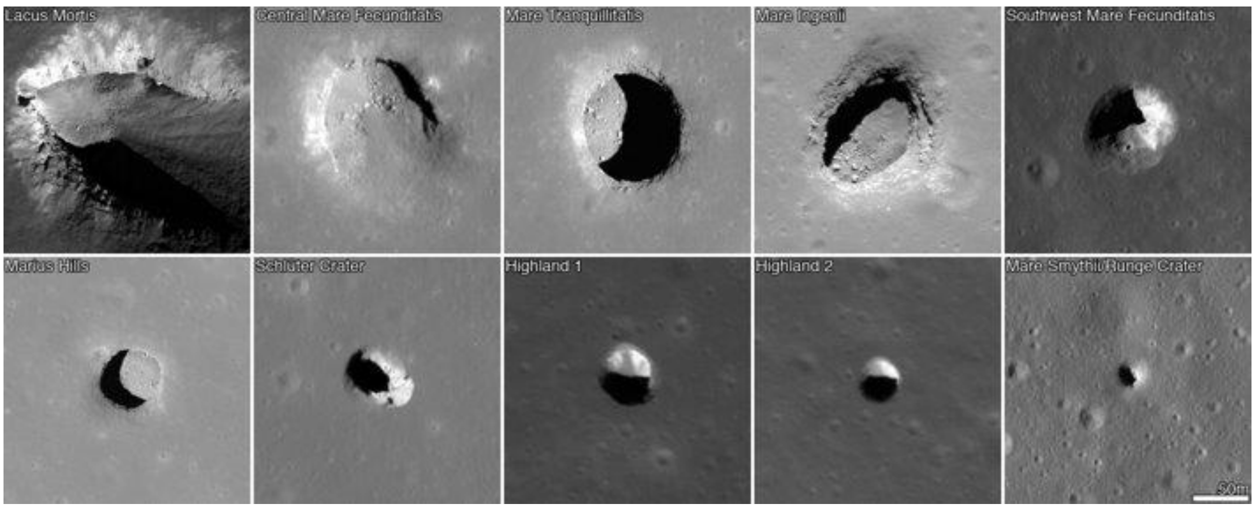

Figure 1 - Lava tubes on the Moon seen from the space

So, to enter inside a lava tube, there are two options, either from a hole above, or from a side if there's that possibility, and once inside, there's the possibility of finding collapsed tunnels or debris:

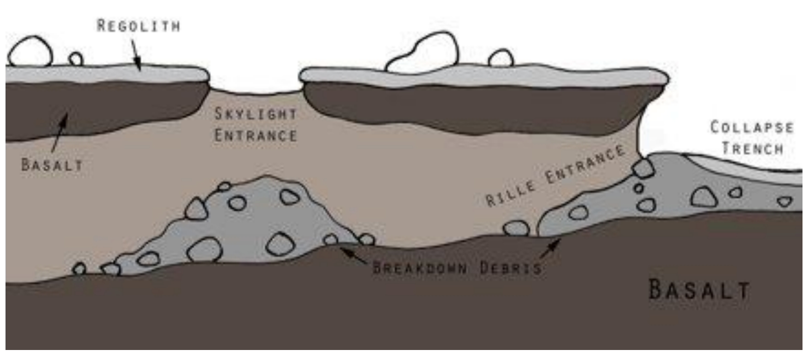

Figure 2 - Sketch of the inside of a lava tube

Since the most common way of entrance was from above, we thought of a possible solution to get the rover (which we called UC-Ebot), which consisted on going down a rope and surveying the surroundings to choose a good landing zone as shown in the next picture:

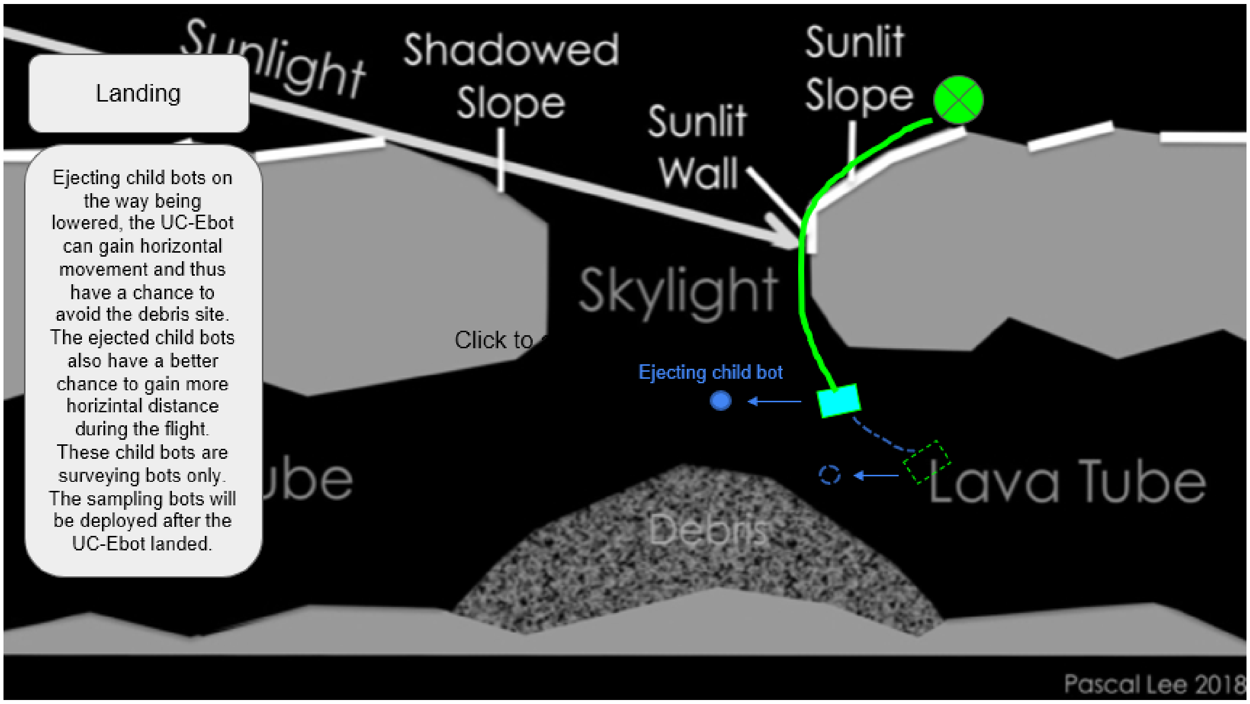

Figure 3 - Possible concept of entering the lava tube

Once we knew the location where our rover would be operating, we had a few brainstorming sessions where we presented possible mobility ideas. Some of the ideas presented were the following ones, between many others:

One of the ideas I personally presented was a system with “screw” or “helicoidal” movement that would require intercalated blocks with opposite helicoidal directions so it could move forward and not just rotate and where the joints should be able to both move and stay rigid to be able to move into any desired direction. The sample collection mechanism could be located at the joints, and the samples could be stored inside the screws. Each block could be attachable/detachable so depending on the mission it can be used as a longer or shorter “snake” and it could be used in a larger or smaller scale. Additionally, lights or sensors could be installed in the front:

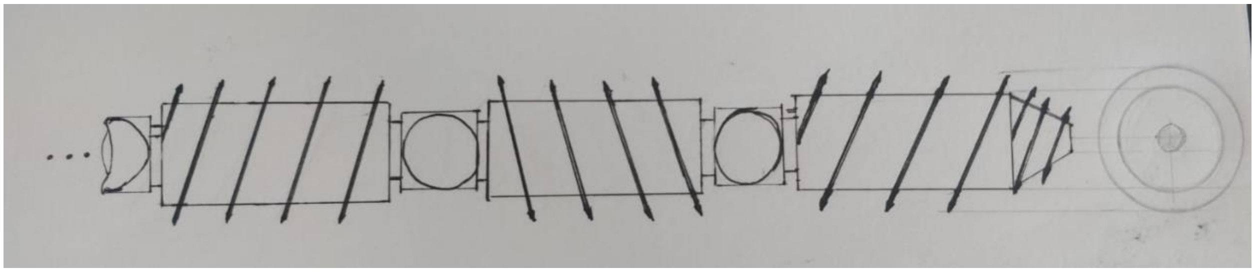

Figure 4 - Sketch of the helicoidal system

Another proposed idea was a movement based on inchworm locomotion, which would be configurable, by adding or subtracting links as necessary. It would have a head link that could have the brains and other links could have specific capabilities. And it could be made simple, by operating primarily with linear actuators. The concept is shown in the next picture:

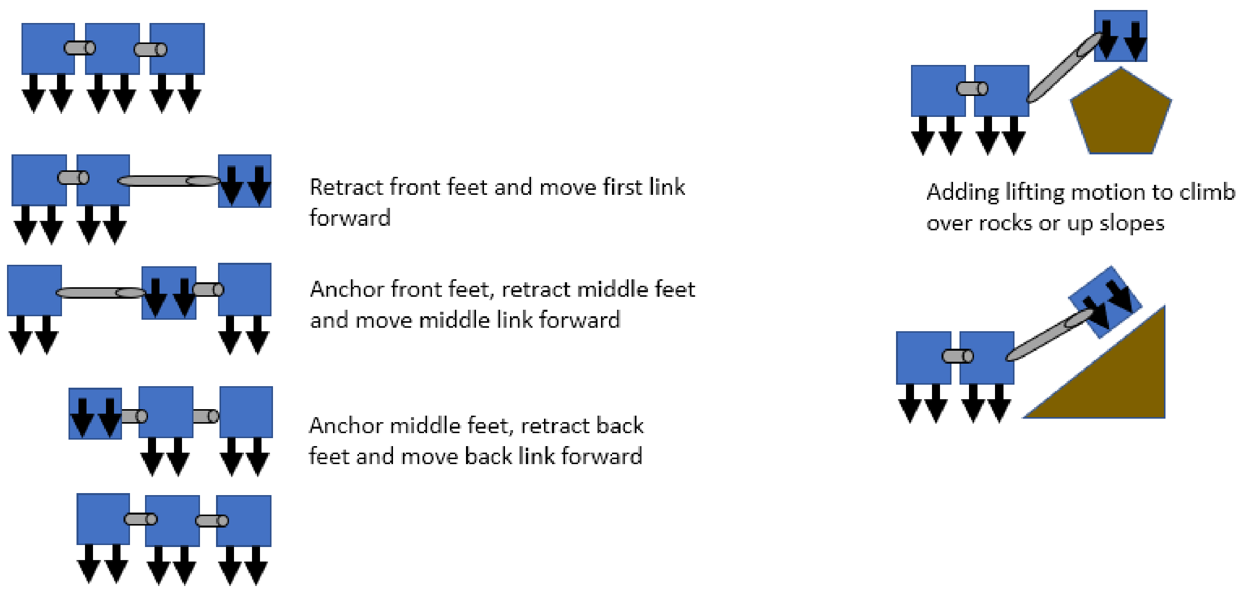

Figure 5 - Concept of the inchworm locomotion

Other examples include:

·Snake climbing robots:

Concept by:

Fu, Q., & Li, C. (2020). Robotic modelling of snake traversing large, smooth obstacles reveals stability benefits of body compliance. *Royal Society open science*, *7*(2), 191192. [2]

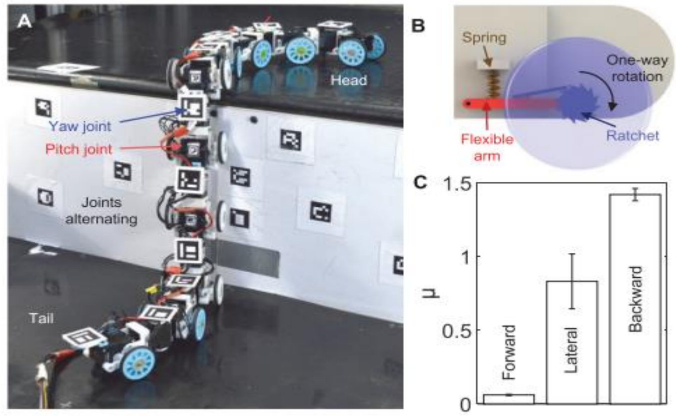

Figure 6 - Snake climbing robot

·A water-slider-like concept that could jump, with the next properties:

- Falls with four legs fully extended (skydiver). Adds cusion to fall
- Jump by contracting legs
- Walk with typical gait
- Low CoG
- > 4 legs possible
- Complex Leg "grip sections"
- Omni-Directional

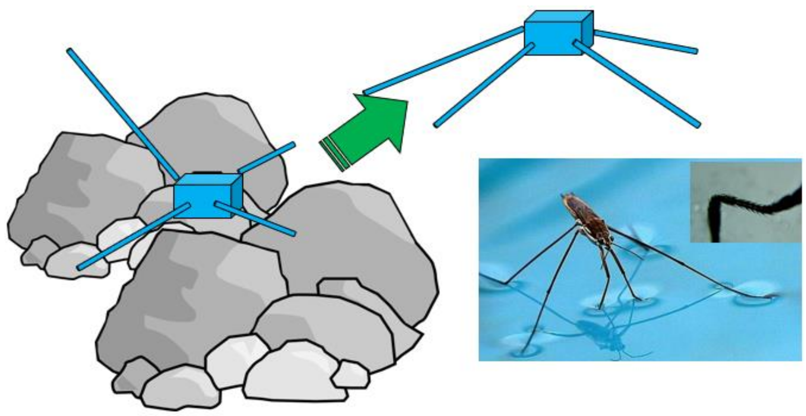

Figure 7 - Water slider concept

·Spherical systems with two hemispheres that can rotate for radiational movement, with a grappling hook:

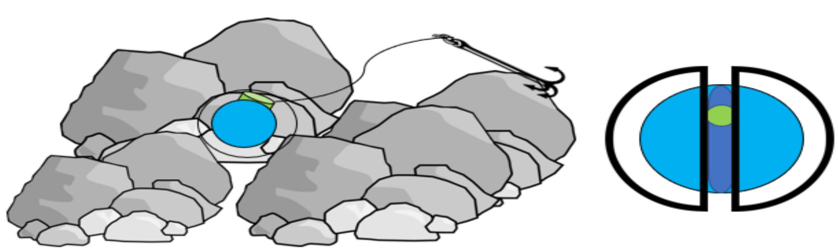

Figure 8 - Sphere with hook concept

We also considered mixing the concept of the helicoidal screw movement to be used as “wheels” for the rover that could later be ditched to explore on their own as in the first concept:

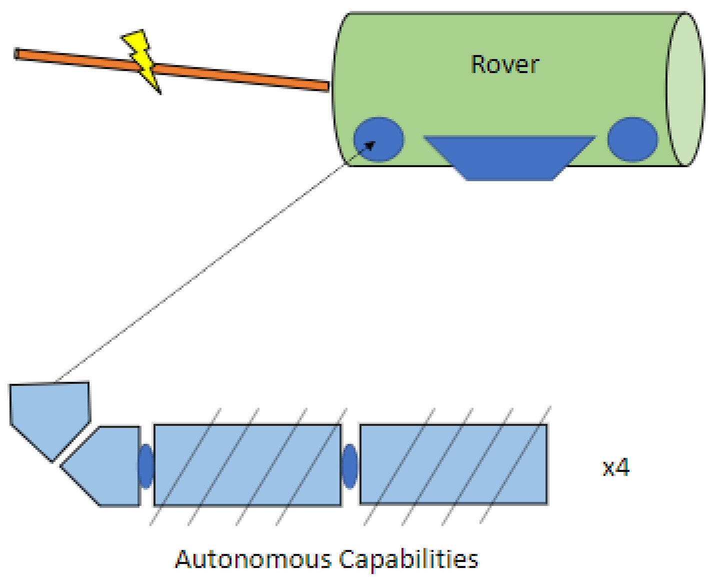

Figure 9 - Rover with the helicoidal movement wheels

After considering all the options, we decided to go with something a bit more complex, involving soft robotics. The concept would be a rover which would have octopus-like legs, and where each of those legs was formed with different sections resembling a snake robot. Additionally, each leg would be formed by different segments, each one with a different role:

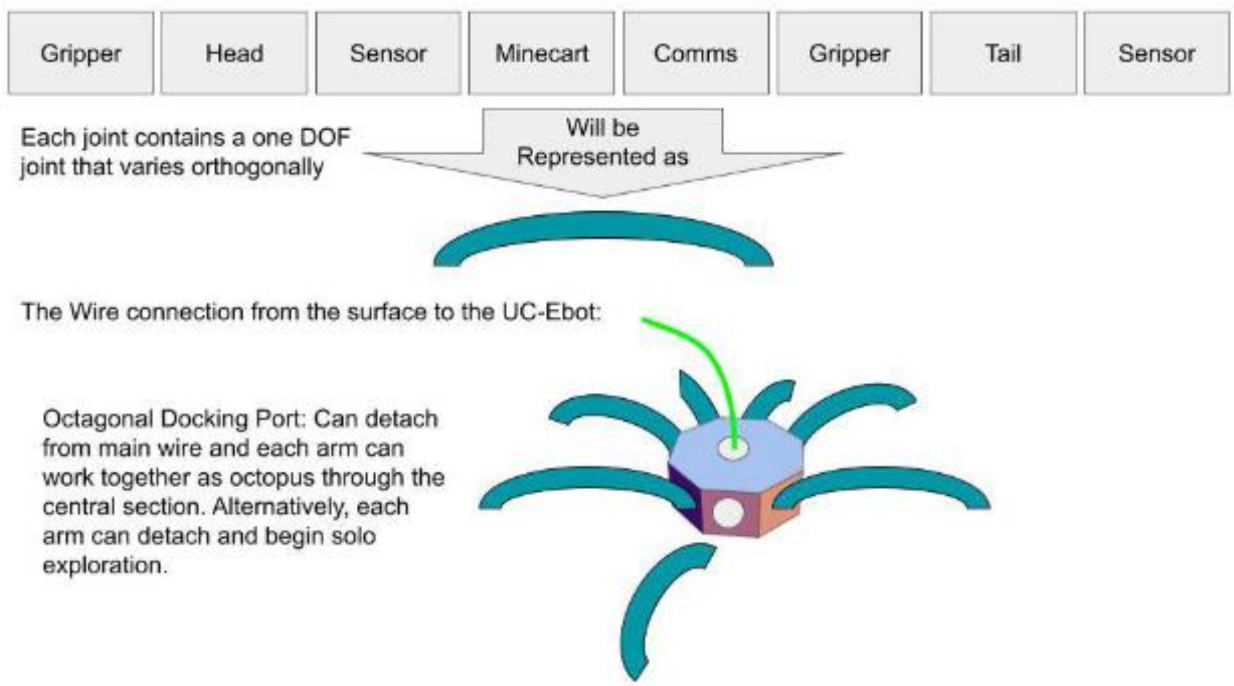

Figure 10 - Concept of the UC-Ebot

·Gripper: A segment that contains specific parts meant to increase the friction between the segment and then lunar rocks.

·Sensor: An empty segment that can be filled with mission-specific parts.

·Minecart: A proposed segment that stores samples that are collected by a drill segment.

·Head & Tail: The important power supply and communication parts are stored here.

·Comms: A space for relay storage and long-range wireless communication.

We chose this design because it has to be able to overcome any obstacle thrown at it. This includes 80-degree walls, large boulders, rubble, long halls and ground fissures between others. A reconfigurable design will increase the potential solutions that solve any given terrain-related problem.

Additionally, this way, cheaper and reusable segments can be used, because so much of a segmented approach relies on the ability to replace damaged parts, leave behind parts that are not needed, and adapt as the robot encounters obstacles. The ability to quickly re-outfit a salvaged robot and get it back to exploring is more valuable and reconfigurable designs mean that any segment should be able to connect to any other segment. For example, if the head and tail segments are rendered inoperable, then the rest of the robot would be dead. Rescue missions, where another snake is sent in to connect with and ultimately recover a damaged segment could be considered.

RESULTS AND CONCLUSSIONS

To be able to develop a rover with a novel mobility system that could move around the lava tubes located in the moon, we had to study all the possible complications and think about a design that could overcome them all. For that, we met and discussed different possibilities, reaching to the conclusion that a reconfigurable design would be the best solution. Additionally, it could repair itself in certain situations.

BIBLIOGRAPHY

[1] 2022 Extreme Terrain Mobility Challenge Details | Big Idea. (2020). https://bigidea.nianet.org/competition-basics/

[2] Fu, Q., & Li, C. (2020). Robotic modelling of snake traversing large, smooth obstacles reveals stability benefits of body compliance. Royal Society open science, 7(2), 191192.

[3] Shared documents and ideas inside the team.