NASA SPACE APPS ARACAJU, 2019

CHALLENGE “EENY, MEENY, MINEY, SAMPLE!”

TEAM *KEPLER-N*

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Abstract

Know the moon and have insights to improve human life. Why not? We are in a hurry, and to better enjoy every second that life offers us, we need to know quickly and live the experience of creating, improving and developing new solutions. Based on our wish, we recognize the need for cheaper, efficient and feasible analyzes in a short time, providing in situ sample screening with information transmissions to Earth, thereby promoting financial, logistical and time saving in missions. Kepler-N is a robotic mission of Kepler Mother and Kepler Babies with a scalable, automated system capable of accurately identifying favorable sampling points, performing in situ screening and transmitting scientific information to the earth, reducing the cost per sample kilogram. Lunar transported for analysis on Earth, shipping time and financial aspect. Thus, the Kepler project impacts on the quality of the analyzes performed, optimization of scientific work and attaches value to lunar findings.

Index

Introduction

All Apollo missions from Apollo 11 in July 20, 1969 to Apollo 17 in December 7, 1972 brought back a total of 2,196 samples totaling 382 kilograms (842 pounds) **[1]**. As the missions progressed, the number of samples increased from 58 to 741 - with various rock types which were duly classified after reaching Earth. Through gamma-ray and X-ray fluorescence data from satellites and telescopes, we have interpretations of the global distribution of lunar rock types, which are the basis on which sample collection is based **[2]**.

However, lunar samples are too few; much of lunar history is still shrouded in mystery, as well as its violent past inside our Solar System. There are currently three sources of lunar samples available on Earth - 381.7 kg of rock and soil collected by the Apollo missions, 321g of lunar soil excavated up to 160 cm into the moon surface by the Luna missions; and lunar meteorites collected on the Antarctic ice cap by the U.S.A. and Japan. All of them come together to tell a story which is naturally incomplete, because they only describe a small part of the Moon **[2]**.

This project aims to identify details about the regolith in specific areas of the moon, through the principle of simple analysis by smaller robots chaperoned by a more capable rover - the “Kepler-Babies” and the “Kepler-Mother”. Through analysis of the YUTU Chinese Lunar Rover **[3]**, the retired NASA VIPER (Virtual Intelligent Planetary Exploration Rover) **[4]** and possible adaptations from the smaller Mars rovers “Spirit” and “Opportunity” **[5]**, we aim to start a minimum viable network of lunar exploration which can scale up to a Moon-wide sampling initiative **[6]**.

The “Kepler-Baby” can also benefit from the development of CEDRA (Meghdari et al., 2005), a rescue rover with its structure similar to the shrimp, based on the genetic algorithm technique for adaptation to the environment. Following this principle, the “Kepler-Baby” is a lunar exploration rover which will be build from simulated genes from successful rovers, such as Curiosity, Lunokhod I, Lunokhod II, Spirit and Opportunity **[19].**

Project Importance

Through NASA's own initiative of returning to the Moon by 2024 through Project Artemis **[20]**, as well as the incentive for novel solutions through the Commercial Lunar Payload Services (CLPS) **[21]**, humanity begins to regain a foothold on its closest celestial body. In order to reach the ambitious goal of a five-year schedule, there is a need for cheap, scalable techniques which can precisely analyze the regolith - gathering enough data over where and how to build.

This project's aims in studying the moon in a cost-effective manner - through automation and large-scale coverage of strategic spots on the surface - is aligned with NASA's objectives of a safe, successful and efficient human presence on the Moon **[23]**.

With the execution of this project, NASA gains a tool for cheap and thorough analysis in any solid celestial body, which can be applied on further exploration of our Solar System.

Viability

According to the challenge of evaluating lunar samples quickly and effectively before a tripulated mission - and classifying samples as to their potential scientific value - Kepler-N plans to make use of established tools already used by NASA in exploration, in a different relationship between mobile elements.

In its Mars Curiosity Rover, NASA already makes use of several tools which project Kepler-N aims to apply in its low-cost, “baby” rovers - mainly the Fourier Transform Infrared Spectoscopy (FTIR) and the Alpha Particle X-ray Spectometer (APXS), which provide a basic but complete analysis of rock&soil; as well as percussion drills, brushes and mechanisms for scooping, sieving and portioning samples of powdered rock and soil **[7] [8]**. In December 2003, a a smaller and cheaper probe called Beagle 2 was launched, finding problems with solar panel deployment - but demonstrating a safe landing with rovers costing as little as US$80 million each as opposed to US$2.5 billion for the Mars Curiosity rover **[9]**.

As for the larger “mother” rovers, the technology already exists for their mechanical operations - communications by X-band transmitter and receiver which can communicate directly with Earth, and a UHF Electra-Lite software-defined radio for communication with Mars Orbiters. **[10]**; mobility through six 50cm diameter wheels in a rocker-bogie suspension **[11]**; scientific instruments include Linear Energy Transfer Spectrometer, Near-Infrared Volatile Spectrometer System, Neutron Spectrometer System and Advanced Neutron Measurements at the Lunar surface, and Ion-Trap Mass Spectrometer for Lunar Surface volatiles are already in use and planned for possible lunar flights in 2019 **[12].**

Between 1969 and 1972, Apollo astronauts brought 382 kilos / 800 pounds from six landing spots **[13]** which can be improved today through the use of new technological resources already applied in space missions – making the process of sampling easier through mapping and analysis.

Sample value is linked to its particularity, being essential for lunar findings and with unique importance when not found on Earth. Sample element percentages, the potential for water and the possibilities for rare-Earth metals **[14]** may unveil soil properties and open possibilities for new materials.

This project aims to evaluate and recognize scientific engineering value from each mission through *in situ* sample evaluation, executing complex analysis only on scientifically relevant samples. It will achieve this objective through a robotic mission which aligns to the capability, sturdiness and improvements upon the NASA rovers VIPER and Mars 2020 and the Chinese Yutu **[15]**.

Problem to be Solved

The problems proposed in the NASA Space Apps Challenge “Eeny, Meeny, Miney, Sample!” are as follows:

You are the astronaut/robotic mission lead tasked with bringing valuable specimens from the Moon back to Earth for further study. How will you evaluate lunar samples quickly and effectively before or while still on the mission? How will you differentiate samples of potential scientific value from less interesting material?

The problem emphasizes the difficulty in evaluating samples in a fast and effective way before or during a mission. Thus, the greatest pain arises from the redundancy of samples, which generate negative impacts of financial and logistical nature.

Engineering Objective & Hypothesis

The construction of the "Kepler-N" with its built-in technological equipment and resources for discernment samples, analyzes, generating results through signs and send the same contribute to the elucidation of the chemical composition of the lunar surface, with promising knowledge for the development of new materials and technological resources for Earth, being of inventive and innovative character the reduced cost with the operation when compared to the already executed processes.

Schedule

Activity / Phases	1	2	3	4	5
Literature review and survey of lunar expeditions data (mappings, analyzes performed, apparatus used, financial values and related).	x				
Definition of the analysis parameters for pre-analytical sample sorting and classifying analysis (Kepler Baby).	x				
Outline analytical sequence and validation processes to be performed on Kepler Mother.		x	x		
Creation of genetic algorithm for prototyping of the minimum viable product.		x	x		
Kepler-N development and realistic simulation.				x	x
Measurement of Results				x	x

Method Description

After applying the analysis techniques on the Moon by the satellite in orbit, a set of characteristics mapping are divided into regions where a bio-inspired algorithm for the discovery of the Kepler Baby's route is applied. The applied algorithm is based on the bee swarming behavior, also called bee clustering **[23]**. This can identify optimal routes through various groups of variables.

Kepler-Baby Route

In order to determine the Kepler-Babies routes before landing, satellite-imaging analysis of the Moon is executed, after which a matrix is generated in which each cell corresponds to a series of characteristics defined by the images. The sets of a cell's characteristics also correspond to the same region in lunar soil. Afterwards, the bee-clustering bio-inspired algorithm is applied using the following EMMS (Eeny, Meeny, Miney, Sample!) Fitness Function:

$$EMMS : \sum_{i=1}^{m} a_i M_i$$

In which:

a_i = Priority of the material M_i

M_i = Amount per cm³ of material defined by characteristics from region i mapping.

The bee-clustering algorithm then creates a group of same-characteristics material and then plots a path between similar groups as to determine Kepler-Baby destination, as illustrated below:

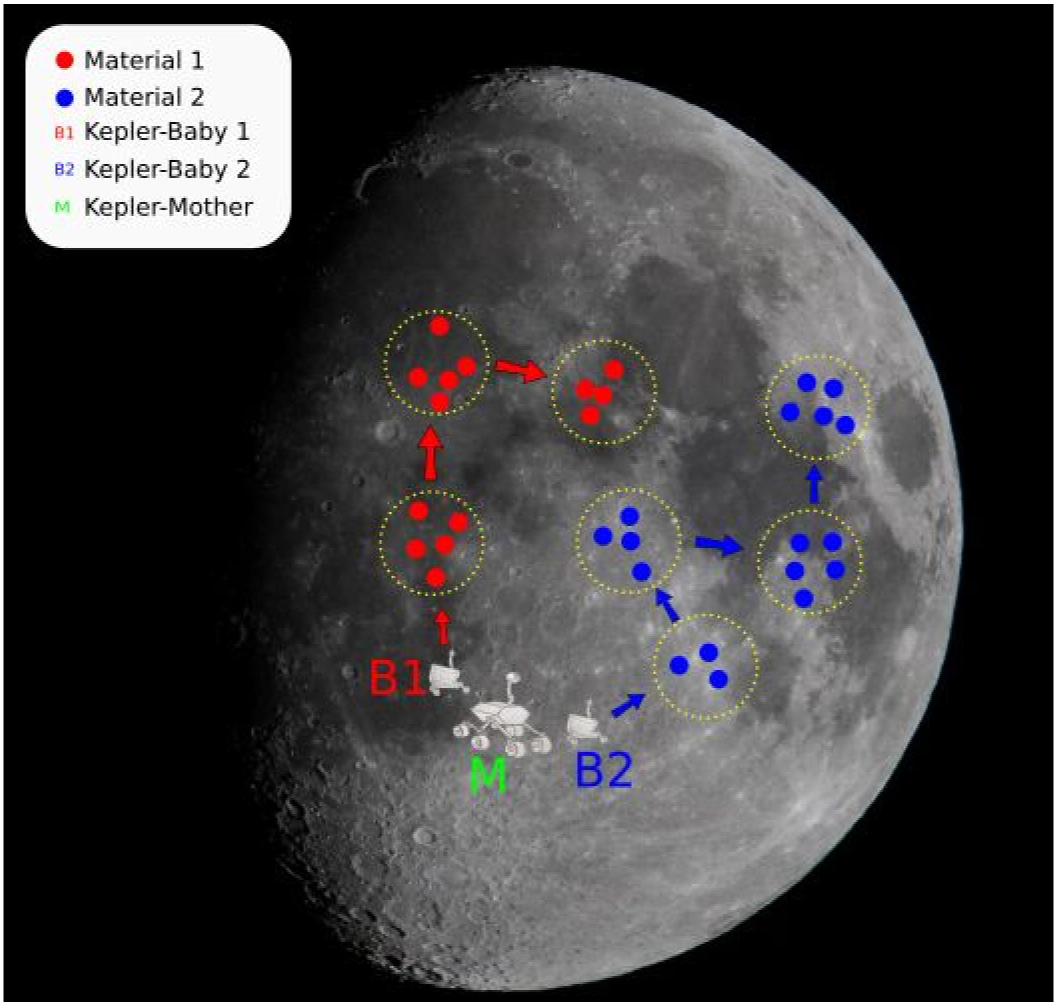

Figure modified from: https://www.flickr.com/photos/nasahqphoto/47421185351/in/album-72157677281368037/

Kepler-Baby and Kepler-Mother

Kepler-Baby, by scanning and obtaining macroscopic information, will be able to identify interesting regions to obtain samples of different natures, such as rocks, their fragments, and dust. In addition to spraying and homogenizing samples, it performs pre-analytical and analytical screening steps on its structure. Samples considered valid are taken for more robust analysis at Kepler-Mother or even stored for future shipments to Earth from the results obtained by the validation algorithm.

The Kepler-Mother specialized analysis station will have storage capacity for samples analyzed by Kepler-Babies, portable X-ray fluorescence spectrometry, X-ray diffractometry (XRD) analysis and other techniques. It also relies on efficient communication with NASA's technology foundations on Earth.

As proposed in the schedule, we intend to develop from a sample validation instrument, performing more robust analyzes while aiming to identify samples of scientific value and potential economic value to the construction of a neural network aiming to unify lunar mapping data. The library with data from gathered control data and analysis grouping in order to obtain answers about the sample validity while eliminating redundancies.

The record of observations, challenges, ideas, descriptions, measurements, annotations, data and results will be recorded in the Project Logbook as to report and measure the team's trajectory during project execution.

One of the main points is the elimination of redundancy in data of collected samples, sending it to Kepler-Mother to be registered and stored for the future. The solution is to apply a clustering algorithm to the data to group and classify it – so that when it already exists in the database it will be discarded in the future by Kepler-Babies.

The following are Kepler-Baby's and Kepler-Mother's technological and/or innovative suggestions:

- Maximization of information from topological analysis to assist in choosing optimal points for exploration;
- Geographic record of the mapped area and collection points for consideration and future study possibilities;
- Adhesive tapes for collecting suspended materials with and without impregnation of indicator substances, aiming to quickly and accurately characterize analytes of interest;
- Tape reader scanner capable of qualifying analytes and generating morphological results;
- Sample sprayer with collection, homogenization and analysis;
- Efficient sample screening capable of approving according to possible values for the sample, considering significant possibility for structural, property, process and performance parameters.
- Use of the portable X-ray fluorescence spectrometry technique for the purpose of comparing materials, being chosen for the advantages of the speed and the non-destructiveness of the analyzes that it processes, also standing out for the sensitivity to the surface effects, being the dust impregnation in the samples contoured by minor surface abrasions **[16]**;
- Analysis of total sample sprayed by x-ray diffraction (XRD) aiming to characterize crystalline structures **[17]**;
- Infrared spectroscopy accompanied by Fourier transformation to recognize potential gases such as helium, as well as metal oxides and water in the regolith **[18]**.

Potential Considerations

- The limitations of the idea such as the mobility of Kepler-Babies and the adherence of dust fragments can be solved by co-creating with other teams engaged in the corresponding challenge;
- For the purposes of this project, the value of a sample is considered to be any characteristic or property determined by on-site analysis or by data complemented with simulations at analysis stations on Earth, that may demonstrate enrichment of scientific knowledge and application feasibility / feasibility, as well as the improvement of human life;
- The techniques and technologies, as to their inventive and innovative character, are all viable for the execution of this project - considering the concepts approached, the research used for creating its design, and training of engaged members.

Future Perspectives

- Determine, accurately and precisely, lunar samples *in situ*;
- Save astronaut hours on missions, as well as optimize science production at technology stations;
- Volume reduction of non-valuable samples transported to Earth;
- Identify materials with potential application in transistors, photovoltaic panels and other solid-state electronic devices;
- Search for biocompatible materials that can be used in the manufacture of medical implants;
- Applications in metallurgy, with proposals for alloys with different characteristics and properties with discovered iron, aluminum or nickel;
- Obtaining materials with potential for use in mechanics and construction;
- Create conditions to perform comparative analysis by evaluating the behavior of samples under lunar and Earth conditions.

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