Autonomous navigation system for CURIOSITY Mars rover using SPOC algorithms.

Muhammad Uzair Khuwaja#1, Qamar Hasnain Memon\*2.

#Software Engineering Department, Mehran University of Engineering and Technology Jamshoro Pakistan.

119SW45@students.muet.edu.pk

219SW116@students.muet.edu.pk

Abstract— This paper discusses how the curiosity mars rover navigates on the surface of mars, the challenges presented to it while doing so, and how the navigation system of the curiosity mars rover can be improved, the main focus of this paper will be to discuss what changes in the AI model of the curiosity mars rover can be made to provide a time efficient and safe navigation system.

Keywords— Martian-day, sol, here, keywords are separated by comma.

1. INTRODUCTION The curiosity mars rover, developed to collect soil samples from the surface of mars and map out the terrain of the planet. in the 6 hours of awake battery time that it has, the rover can only travel 30.48 meters (100 feet) on the surface of the mars each sol (Martian-day). so, to improve that and save the precious time, a new autonomous AI based methodology will be introduced, using which the mars rover will be able to go even farther distances. [1]
2. Current navigational method

As of now, the curiosity mars rover has no means of autonomous navigation, for driving, Curiosity takes a series of stereo images around the rover with its navigational cameras (NAVCAM) when it finishes moving for the day. The rover team makes a mosaic from the overlapping images and projects it onto the ground. The team present at earth then compare this ground-projected image, called an orthophoto, with the base map of the planet that we have so far. The path for the rover to cover the next day is then calculated and instructions are sent to the rover as early in the next sol as possible.[2]

1. Resource challenges faced

Due to the huge distance between earth and mars (239.15 million km), there is a significant communication gap between the team at earth and the rover, almost 20 minutes. due to this arrangement, the following challenges are to both the rover at mars, and the team at earth.

1. No live data transmission.

Unlike a remote-controlled car, the drivers of rovers on Mars cannot instantly see what is happening to a rover at any given moment and they cannot send quick commands to prevent the rover from running into a rock or falling off of a cliff.[1]

1. Huge calculational efforts.

Due to the huge delay the path the rover has to follow should be calculated in advanced which is no easy thing to do.

1. Time waste

There is a huge under-utilization of time, if the time that the rover has on the red planet (Mars) can be better utilized, we might be able to reach our goals earlier.

# 4. PROPOSED SOLUTION

Since the communication delay between earth and mars is too long, it would better serve us to have an automated AI based system to navigate at the dangerous terrain of mars.

SPOC (which stands for Soil Property and Object Classification) is a class of software capabilities that utilizes machine learning to classify terrain types from imagery.

Terrain has been a major source of risk for Mars rovers. Spirit (a previous mars rover) was embedded in sand and ended its mission. Curiosity also has experiences of getting stuck in sand, although it has been able to escape.

SPOC’s autonomous terrain classification capability helps human rover drivers on Earth, as well as on-board algorithms,

to drive safely on the red planet.[3]

5. HOW THE MODEL WOULD WORK

SPOC is a family of algorithms.

SPOC-HiRISE and SPOC-NAVCAM are based on deep convolutional neural networks, and are intended for use on ground operations. SPOC-Lite and SPOC-HPSC/SNPE are intended for on-board deployment, with SPOC-Lite employing a simpler ML model runnable on CPUs, while SPOC-HPSC/SNPE are based on deep learning and use GPUs.

SPOC-Lite is an on-board terrain classifier compatible with a RAD750-class CPU. Taking monaural images as an input, it outputs the probability of sand on the image which can be used to avoid the tragedy that the spirit rover had.[3]

# 6. DISSCUSSION

By implementing the autonomous object and sand classification using the SPOC model, the precious time and efforts of the team at mars can be saved, this would mean that the time and effort can be used elsewhere such as training the model for better results. Using an autonomous AI model brings about collective and collaborative effort of both the said model and the team at earth. This setting helps us get better results and reduce the under-utilization of time and efforts faced in earlier settings.

# 7. Performance Evaluation

For reporting the terrain classification performance of SPOC-H the area of Columbia Hills was used, which is a candidate landing site for M2020 as well as the destination of the MER Spirit rover.[4]

|  |  |  |
| --- | --- | --- |
| S.NO | Class | Definition |
| 1 | Smooth Regolith | Terrain that is not solid bedrock, but that is a firm surface without obstacles or significant terrain features. It is expected that the grousers will penetrate the regolith, but that the skin of the wheel will not see any substantial sinkage. The regolith has enough shear strength that the rover slip will be minimal. |
| 2 | Smooth Outcrop | Outcrop that is solid such that the wheel grousers will not penetrate in to the terrain. The outcrop is smooth with no obstacles that need to be avoided. |
| 3 | Fractured Outcrop | Outcrop that is solid such that the grousers will not penetrate in to the terrain. The outcrop has polygonal fractures that are often filled with sand or regolith, but the fractures do not constitute a mobility hazard and can be driven over without hesitation. There are no obstacles such as loose rocks |
|  |  | on the outcrop that need to be avoided. |
| 4 | Sparse Ripples Firm Substrate | Ripples that are spaced 5 to 25 meters apart over the top of a firm substrate that is easily traversable. The distance between the base of one ripple and the base of the adjacent ripple is wide enough that the rover can traverse through the ripple field without needing to drive on the sand. |
| 5 | Moderate Ripples Firm Substrate | Ripples that are spaced 1 to 10 meters apart over the top of a firm substrate that is easily traversable. The distance between the base of one ripple and the base of the adjacent ripple is not always wide enough to enable passage of the full rover width without the rover driving on the ripple, |

# 8. CONCLUSIONS

The current setting for navigating the mars rover using drivers at earth who set a path by making calculations from the images sent by the curiosity rover and comparing them with the already available base map is not utilizing the resources of both the team at earth and the rover itself, thus a AI model named SPOC (Soil Property And Object Classification) is used which can automate the work of scientists at ground and classify the objects such as rocks and sand for the rover, which it can use to safely navigate, the ground team also provides its support in this regard since its not able to fully automate its path yet.

In the future it can be hoped that the SPOC model or some other better model can be made such that it can fully automate the driving of the Curiosity rover, for now, its just a dream for many, but its looking like a dream that’s within reach in the light of most modern technology.

# REFERENCES

1. "Moving around Mars", *Mars.nasa.gov*. [Online]. Available: https://mars.nasa.gov/mer/mission/timeline/surfaceops/navigation/#trav erse. [Accessed: 07- May- 2022].
2. N. Cappellina, "How does NASA navigate a Mars rover's direction and determine its loc", *Astronomy.com*, 2014. [Online]. Available: https://astronomy.com/magazine/ask-astro/2014/11/steering-a-rover.

[Accessed: 07- May- 2022].

1. "SPOC - Soil Property and Object Classification Algorithm", *Nasajpl.github.io*. [Online]. Available: https://nasajpl.github.io/SPOC/#:~:text=SPOC%20(which%20stands%20for%20S oil,classify%20terrain%20types%20from%20imagery. [Accessed: 07- May- 2022].
2. J. Papon, R. Kennedy, M. Masahiro Ono and M. Heverly, "SPOC: Deep Learning-based Terrain Classification for Mars Rover Missions | AIAA SPACE 2016", *AIAA SPACE Forum*, 2018. [Online]. Available: https://arc.aiaa.org/doi/10.2514/6.2016-5539. [Accessed: 07- May- 2022].

(PHY) Specification, IEEE Std. 802.11, 1997.