Simulation of Mars Curiosity Computer Vision for Low Cost Autonomous Navigation System. O.B. Swida[1a,2], B. H. Foing[1,2], C. A. Vleugels[1b,2], [1]Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands ([a]swida@strw.leidenuniv.nl, [b]vleugels@strw.leidenuniv.nl), [1]LUNEX EuroMoonMars Earth Space Innovation and EuroSpaceHub Academy (foing@strw.leidenuniv.nl)

Introduction: Curiosity rover has been deployed and working Gale Crater on Mars since 2012, therefore it has been 10 years (sol 3706). Since then it has undergone a lot of wear and tear, including some holes in the rover's wheel [1] and the Rover Computer Element (RCE) issues [2].

Figure 1 – The wheel condition of Mars Curiosity on sol 3672 (5 December 2022). Credits: NASA/JPL-Caltec [1]

Previously, Mars Curiosity Rover uses combination of on board computing algorithms and input from the control system on Earth. But the current 3 available systems of autonomous navigation system (blind-drive, blind-drive, visual odometry, and visual odometry with hazard avoidance) [3] that are available for Mars Curiosity Rover might either be insufficient on detecting hazardous objects and/or takes up too many resources in the deprived computational condition on board.

The Mars Express (MEx) orbiter and Mars Reconnaisance Orbiter (MRO) have already imaged a huge portion of Martian surface. But the highest resolution from High Resolution Imaging Experiment (HiRISE) is only in the order of a meter [4]. Therefore it is required that the rover can detect (small) hazardous objects along its path.

Background: Since November 2018, Mars Curiosity has some memory issue on both of its Rover Computational Elements (RCE) [5]. Limiting the computational resource available to operate the rover. Reaching Aeolis Mons (informally known as the Mount Sharp), the demand of path determination is high since the ground is no longer on a flat surface. With the assistance of orbiter images, we can roughly determine the safest path to navigate through the terrain.

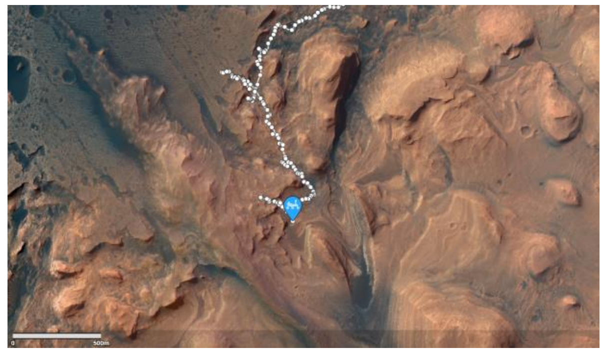

Figure 2 – Mars Curiosity path and surrounding terrain, obtained from HiRISE cameras on NASA's Mars Reconnaissance Orbiter. Credits: NASA JPL [6].

Methodology: With the limited capabilities of the RCE, Mars Curiosity demands an algorithm that is not too resource intensive but with high accuracy. Therefore, this research is aimed at developing a simple algorithm with low computational cost.

Some authors has already shown the result of using convolutional neural network [7], LIDAR [8][9], or Scaled-YOLOv4 classifier [10]. While the results are good, but the process is not computationally cheap especially for the conditions given.

Using the instruments available on Curiosity, we can try to use the image cameras (i.e. Mastcam) to detect objects near the rover, determine the slope of the terrain, and determine hazardous objects based on the shape, size, and probability density of the object. We hope that this algorithm can be applied to future missions, to reduce the computational cost of the mission.

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References:

[1] NASA/JPL-Caltec. *Image was taken by NAV_LEFT_B onboard NASA's Mars rover Curiosity on Sol 3672 (2022-12-05T02:38:39.000Z)*. Retrieved on 10 January 2023.

[2] NASA. (2019) *Curiosity Resumes Operations After Switching Computers*. Retrieved from https://mars.nasa.gov/news/8416/curiosity-resumes-operations-after-switching-computers/?site=msl on 10 January 2023.

[3] Grotzinger, John P. et al. (2012) *Mars Science Laboratory Mission and Science Investigation*, Space Science Reviews 170, 5–56.

[4] NASA/JPL-Caltec. *HiRISE.* Retrieved from https://mars.nasa.gov/mro/mission/instruments/hirise/ on 10 January 2023.

[5] NASA. *Curiosity on the Move Again*. Retrieved from https://mars.nasa.gov/news/8371/curiosity-on-the-move-again/ on 10 January 2010.

[6] NASA. *Where is Curiosity?*. Retrieved from https://mars.nasa.gov/msl/mission/where-is-the-rover/ on 10 January 2023.

[7] Neil Abcouwer et al. (2020). *Machine Learning Based Path Planning for Improved Rover Navigation (Pre-Print Version).*

[8] Tara Estlin et al. (n.d.). *Continuous Planning and Execution for an Autonomous Mars Rover*

[9] Erick Dupuis et al. (2006). *Continuous Planning and Execution for an Autonomous Mars Rover.*

[10] David Noever and Samantha E.M. Noever. (2021). *ROCK HUNTING WITH MARTIAN MACHINE VISION*.