

ON ORBIT EXPERIENCE AND CHALLENGES OF VISION BASED PATH PLANNING USING CHANDRAYAN-3 ROVER NAVIGATION CAMERA

Jayanta Laha⁽¹⁾, Amit Maji⁽²⁾, Tanisha Bhatia⁽³⁾, ,Bijoy Raha ⁽⁴⁾,, Priyabrata Senapati ⁽⁵⁾,Y Vijaya ⁽⁶⁾,

⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾⁽⁶⁾ *Scientist/Engineer,Laboratory for Electro-Optics System (LEOS), Peenya, Bengaluru-560058,Indian Space Research Organization (ISRO), Phone: 91-080-2268-5000,jayantlaha@leos.gov.in*

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Abstract

ISRO has performed a precise soft landing in the Chandrayan-3 mission to the Moon on 23 August 2023 , demonstrated the capability of controlling a Lunar Rover PRAGYAN in search of a scientifically interesting area. A pair of state-of-the-art, miniature, monochrome, digital Navigation Camera (NavCam) [1] is mounted on the front side of the Rover to compute the 3D position of the terrain ahead. For interplanetary missions or lunar missions, rovers are used for in situ measurements of scientifically interesting areas. Stereo Cameras are usually low-cost methods to derive 3D information from a 2D image pair. That 3D information is used to detect if the path has obstacles, a high slope, and is traversable by the wheels. Camera-based measurement requires precise calibration and mounting to ensure the required coverage and accuracy of the measurement of the terrain ahead. Stereo matching needs similar performance over the full FOV between the left and right image pairs. Considering the harsh operating conditions on the moon with low mass and power constrain, reliable NavCam operation was challenging[2].

NavCam was designed [3] with a flex rigid PCB, lightweight optics, and housing. It consists of a low-power radiation-tolerant FPGA driving a space-qualified CMOS detector. The data is transferred to the Data handling system, and command for various parameter tuning are received through the LVDS interface. NavCam was focused on maximizing the depth of the field to get DEM generation over the full path.

Test and calibration is an utmost important aspect of making a mission-critical Navigation camera[4]. Electro-optical performances of NAVCAM were verified in front of a uniform light source, and non-uniformity correction was done. Image sharpness was verified with Modulation transfer function measurement using a different method. NavCam has undergone various environmental testing (EMI-EMC, Thermovaccum, vibration, Shock), and at each phase, camera performances was verified. Left and Right NavCam alignment was ensured during mounting on the rover, and it was calibrated with a 3D target[5] as well as with a Chessboard pattern. This calibration data [6] was used post-landing to generate a 3D point cloud from the stereo image.

NavCam was switched on just after the ramp deployment, and in front of that chessboard pattern was imaged along with the lunar surface. This chessboard image was compared with the ground data, and calibration was ensured. The exposure time of the camera was adjusted, and further imaging was done to generate the best quality images. These images were used for DEM generation [7] and path planning [8]. Path planning of lunar terrain under different lighting conditions was challenging due to the presence of slope, boulder, occlusion due to a big boulder, and crater. A combination of conventional as well as innovative strategies is taken to safely navigate in rough

lunar terrain. With multiple images taken at different angles with different exposure times, NavCAM images helped PRAGYAN rover to complete 100m traversal successfully and perform valuable in situ measurements.

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