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Author: Dr. Giuseppe Tomasicchio
Telespazio, Italy, giuseppe.tomasicchio@telespazio.com

Ms. Anna Maria Gargiulo
Sapienza University of Rome, Italy, annamaria.gargiulo@uniroma1.it
Dr. Antonio Genova
Sapienza University of Rome, Italy, antonio.genova@uniroma1.it
Mr. Simone Andolfo
Sapienza University of Rome, Italy, simone.andolfo@uniroma1.it
Mr. Edoardo Del Vecchio
Sapienza University of Rome, Italy, edoardo.delvecchio@uniroma1.it
Mr. Flavio Petricca
Sapienza University of Rome, Italy, flavio.petricca@uniroma1.it
Dr. Carlo Albanese
Telespazio S.p.A., Italy, carlo.albanese@telespazio.com
Mr. Filippo Rodriguez
Italy, fil74rod@hotmail.it
Prof. maria marsella
Sapienza University of Rome, Italy, maria.marsella@uniroma1.it

LUNAR SURFACE EXPLORATION BASED ON LCNS ORBITERS AND ONBOARD SENSOR OBSERVABLES

Abstract

Lunar exploration is a strategic priority to develop and experiment technologies that will pave the way for the future missions to Mars and to other celestial bodies of the solar system. Robots are expected to prepare the return of humans to the Moon by surveying landing sites, demonstrating in-situ resource utilization (ISRU), and expanding our access capabilities to difficult areas, i.e., craters and caves. Succeeding in these challenging tasks requires reliable and efficient navigation and communication capabilities. Therefore, space agencies are encouraging the development of a Lunar Communication and Navigation Service (LCNS) infrastructure to efficiently support lunar assets. Such a dedicated LCNS constellation would lead to unprecedent advantages in future missions by enabling a constant contact with Earth, even in case of Direct To Earth (DTE) link unavailability, e.g., on the far side of the Moon.

To fulfill critical tasks as obstacle avoidance, instrument maneuvering and reaching a precise location on the map, rover near real time positioning is a key requirement. Thus, in our work we investigate a method based on an Extended Kalman Filter (EKF) that implements a multi modal sensor fusion approach to estimate the rover's position and velocity using observables collected by onboard sensors or provided by an LCNS constellation. We focus on a realistic mission scenario in the Moon's south polar region performed by a robotic vehicle mounting onboard sensors to estimates the travel distances (Wheel Odometry, WO) and the heading variation (Inertial Measurement Unit, IMU). Furthermore, the LCNS orbiters are supposed to broadcast one-way radio signals that the rover user terminal can detect and exploit, providing GNSS-like functionalities. The rover's localization is accomplished through dead reckoning during LCNS visibility gaps, using IMU and WO data and accurate Digital Elevation Models

(DEMs) of the lunar surface. Whenever even single pseudorange and pseudorange rate data are acquired by the rover LCNS terminal, these measurements are processed by the navigation filter in combination with IMU and WO dataset, while optimizing the PVT computation in terms of integrity, accuracy and convergence time.

The proposed method copes with highly varying LCNS visibility conditions and would significantly improve rover's navigation on the Moon's surface in regions where DTE is not achievable. Moreover, our results confirm that the LCNS would be a valuable source of information to be exploited in combination with onboard sensors to improve the accuracy of the rover's reconstructed traverse.