

Line-of-Sight Measurement Optimization for Cislunar Multi-Source Information Fusion Navigation

Yaru Zhao⁽¹⁾, Dantong Ge⁽²⁾, Shengying Zhu⁽³⁾, Jiateng Long⁽⁴⁾

⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾*School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China, 13428081618, 1751640512@qq.com, gedt@bit.edu.cn, zhushy@bit.edu.cn, jlong@bit.edu.cn*

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ABSTRACT

The cislunar space is an essential pathway for humanity to embark on interstellar exploration and holds significant strategic importance. Currently, lunar exploration missions primarily rely on ground-based tracking and navigation. As the number of cislunar spacecraft increases and mission complexity grows, traditional methods face challenges such as limited ground resources and communication delays, calling for onboard high precision autonomous navigation. Autonomous navigation technologies can alleviate ground burden and enhance the spacecraft's capability for long-term independent survival in the space.

This paper utilizes the relativistic effects inherent in stellar observations and the artificial satellites distributed in the cislunar space, and proposes a cislunar multi-source information fusion navigation scheme with line-of-sight measurement optimization. Stars are the most abundant navigation landmarks in the space. Through an integration of the angular distance measurement of the stars and the line-of-sight vector measurement of the satellite, high-precision autonomous navigation is expected to be achieved. The measurement bias of the sensor is also expanded into the state vector, and a self-calibration Extended Kalman Filter (EKF) algorithm is designed to estimate the state vector in real-time, reducing the impact of measurement bias on navigation accuracy through online calibration. Under the designed navigation scheme and given the angular distance measurement, a line-of-sight measurement optimization method utilizing maximum entropy reduction as a metric is developed to find the line-of-sight vector that provides the highest information gain. The entropy reduction is defined as the difference in information entropy before and after integrating the line-of-sight direction information. By incorporating the optimization method into the EKF, the specific form of the entropy reduction expression is derived, based on which the optimal line-of-sight measurement is obtained. The effectiveness of the proposed navigation scheme and the optimization method is validated through numerical simulations, demonstrating its capability to achieve high-precision autonomous navigation in the cislunar space.