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Author: Ms. Graciela González Peytaví
Bundeswehr Univeristy Munich, Germany, graciela.gonzalez@unibw.de

Mr. Joachim Clemens
University of Bremen, Germany, jaycee@informatik.uni-bremen.de
Mr. David Nakath
University of Bremen, Germany, dnakath@informatik.uni-bremen.de
Ms. Alena Probst
Bundeswehr University Munich, Germany, a.probst@unibw.de
Prof. Roger Förstner
Bundeswehr Univeristy Munich, Germany, roger.foerstner@unibw.de
Prof. Kerstin Schill
University of Bremen, Germany, kschill@informatik.uni-bremen.de
Prof. Bernd Eissfeller
Bundeswehr Univeristy Munich, Germany, bernd.eissfeller@unibw.de

AUTONOMOUS ORBIT NAVIGATION FOR A MISSION TO THE ASTEROID MAIN BELT

Abstract

This paper introduces an autonomous navigation concept based on optical observations of the Sun and selected planetary bodies. The concept is self-contained and independent from the mission ground segment. It enables autonomous navigation of spacecraft anywhere in the solar system, including spacecraft flying through the Asteroid Main Belt (AMB). Initially the novel navigation concept is introduced with due reference to the literature. The sensor technology involved, the navigation observables and their accuracy is discussed. Secondly, the navigation performance - i.e. position and velocity errors - is analysed for two selected orbit scenarios: an Earth-like orbit around the Sun and an orbit within the AMB at 2.8 AU from the Sun. For each test scenario two estimators are used: an Extended Kalman Filter (EKF) accounting for third body gravitational perturbations and a stochastic particle filter (PF). The results are evaluated in terms of the standard deviations of the available measurements, the frequency of the observations and the number of observations simultaneously participating in the sensor fusion process.

The optical navigation concept introduced here makes use of infrared measurements of a standard attitude Sun sensor to determine direction to the Sun, optical Doppler measurements from a resonance-scattering interferometer to determine the spacecraft radial velocity relative to the Sun and optical cameras to determine the line-of-sight vector towards planetary bodies.

The problem of orbit determination is solved by means of an EKF at an orbital distance of 1 AU from Earth first. This initial test evaluates the benefits of the additional planetary line-of-sight observations as compared to previous concepts based on observations of the Sun only. In a second step, the EKF is substituted by a PF with the purpose of evaluating the sensor fusion capability of the overall system. The EKF and the PF solutions are compared in terms of accuracy of the positioning solution, convergence efficiency and computational requirements.

Finally, the performance of the proposed concept is evaluated for the KaNaRiA mission scenario. KaNaRiA is a feasibility study of an asteroid mining mission targeting asteroids in the main belt. In the

context of the KaNaRiA mission analysis, a parking orbit at 2.8 AU from the Sun has been selected. The orbit is characterized by slow varying geometry relative to the Sun and good observability opportunities of the near planet Jupiter. Part of the KaNaRiA mission architecture consists of several prospecting spacecraft which will fly autonomously to different target asteroids.