Paper ID: 18217
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SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Part 3 (3C)

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VISION-BASED NAVIGATION SYSTEM FOR THE RENDEZVOUS PHASE OF MARS SAMPLE RETURN MISSION

Abstract

Vision-based navigation has been identified as a major enabling technology for the rendezvous phase of the Mars Sample Return mission. The rendezvous starts after the separation of the Orbiting Sample (OS) from the Mars Ascent Vehicle and finishes with the capture of the OS by the Mars Sample Return Orbiter (MSRO). Under ESA contracts, the industrial consortium (GMV and Thales Alenia Space) is developing and validating the autonomous navigation system. The full navigation chain is designed including cameras, image processing (IP) and navigation algorithms, and their optimal implementation (HW-SW). The Mars environment and system-level constraints are analysed in depth. The search phase is the first rendezvous sub-phase. Its objective is to estimate the OS orbit with sufficient accuracy to start the approach phase. The search phase is very demanding for the IP due to the very faint object. Different IP modes are implemented depending on the brightness of the object in the camera frames. The IP techniques are designed to minimize the impact at system-level and to achieve robust detection and identification of the OS. The navigation filter fuses measurements from: image processing (pixel location in the camera frame), radio-frequency sensor (Doppler), and ground orbit determination updates of the MSRO. The measurements introduce strong couplings and correlations in the filter that shall consider the MSRO and OS orbits. A trade-off of innovative, autonomous navigation filters has been performed via extensive Monte Carlo campaign. Unscented Kalman Filter provides the best results in terms of robustness. The navigation filter shall assure the re-acquisition of the OS after several days without relative measurements from the RF-Doppler and the camera. The navigation solution can also work only with camera measurements. In the terminal phase of rendezvous, preceding the capture, the IP shall provide line-of-sight and range measurements. The relative navigation filter is less demanding in terms of cross-couplings and non-linearities. However, the accuracy and limited operational range (i.e. availability) of the distance measurements from the IP is a great challenge for the observability of the straight forced motion. Sensitivity analyses are performed to identify the critical parameters driving the navigation performances. Worst case and robustness tests in the search phase show the capability of re-acquiring the OS after the non-visibility windows (few days). The terminal phase validation campaign will show the capability of camera-only navigation to achieve capture. The validation campaign includes closed-loop simulations using high-fidelity images to demonstrate the navigation performances.