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KANARIA: IDENTIFYING THE CHALLENGES FOR COGNITIVE AUTONOMOUS NAVIGATION AND GUIDANCE FOR MISSIONS TO SMALL PLANETARY BODIES

Abstract

With the rapid evolution of space technologies and increasing thirst for knowledge about the origin of

life and the universe, the need for deep space missions as well as for autonomous solutions for complex, time-critical mission operations becomes urgent. Within this context, the project KaNaRiA aims at technology development tailored to the ambitious task of space resource mining on small planetary bodies using increased autonomy for space navigation and guidance.

This paper focuses on the specific challenges as well as first solutions and results corresponding to the KaNaRiA mission phases (1) interplanetary cruise, (2) target identification and characterization and (3) proximity operations.

Based on the KaNaRiA asteroid mining mission objectives, initially, a mission reference scenario as well as a reference mission architecture are described in this paper. KaNaRiA has been proposed as a multi-spacecraft mission to the asteroid main belt. Composed of a flock of prospective scout spacecraft, a mother ship carrying the mining payload and several service modules placed on a 2.8 AU parking orbit around the Sun, KaNaRiA intends to characterize main belt asteroid properties, identify targets for mining and perform a soft-landing of a heavy mining payload.

Subsequently, the autonomous navigation system design of KaNaRiA for the interplanetary cruise is presented. The navigation challenges which arise in phases (1)-(3) are discussed. Particular attention is given to the sensor-technology readiness-level, accuracy, applicability range, mass and power budgets. In order to navigate in the vicinity of an asteroid the multi-sensor fusion has to solve the task of simultaneous localization and mapping (SLAM). To deal with uncertain and inconsistent information, a belief-function-based generalization of the FastSLAM algorithm is used.

Next to navigation, the objective of the guidance task is the autonomous planning of optimal trajectories according to mission driving criteria, e.g. transfer time and fuel consumption. A transcription method with multiple shooting method as well as the calculation of trajectory sensitivities for real-time optimal control is explained.

Bringing cognitive autonomy to a spacecraft requires an on-board module as a central spacecraft component. This module is responsible for reasoning and decision making regarding selection of potential targets, trajectory selection and FDIR. A knowledge-base serves as a basis for decision making.

To verify and test these methods, a human interactive simulation in a virtual environment is created. In terms of implementation, KaNaRiA's virtual simulation (KVS) offers an easily adaptable and customizable virtual reality system architecture with real-time performance, which is described here.