SPACE SYSTEMS SYMPOSIUM (D1)
Innovative and Visionary Space Systems Concepts (1)

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GUIDANCE AND NAVIGATION FOR CLUSTERS OF EXPLORING PROBES DESCENDING ON SOLAR SYSTEM BODIES

Abstract

The exploration of solar system bodies other than Earth is increasingly carried out by means of a number of co-operating spacecraft, generally including an orbiter, a lander and one or more rover. A possible evolution of this trend, especially regarding the exploration of almost unknown bodies, calls for a fleet or cluster of tens of small identical probes, either similar or even identical, each of them highly autonomous, which should be deployed at the same time on the body to be explored. The very simple architectures of the probes, granted by progresses in miniaturization, should allow to have a large number of them operating in the same mission like a swarm. The advantages of this solution are in the amount of data produced, as this web of probes, once landed, should be capable of providing a global insight, collecting measurements/samples/pictures of a wide area. The flexibility of the scheme will permit to tolerate a possibly high number of probes' failure, due to their relatively unsophisticated behavioural capabilities, while still having interesting results from the survivors.

The paper focuses on the entry phase for such a swarm, looking at the way to design and actually exploit a set of trajectories fitting the particular mission scenario while facing largely unknown environmental conditions. A couple of possible simple guidance laws will be considered, and the navigation phase during the descent will be stressed. In detail, innovative algorithms to estimate the trajectory of each single agent belonging to a set characterized by a global behaviour – in this special case the descent profile – will be tested. These algorithms, known as dense tracking filters, are among the recent findings of the estimation theory as the latest results along the line of remarkable advancement started in the '60s with the introduction of the Kalman filter. They provide a statistically valid knowledge of the state for each probe while considering all of them, and above all they provide better performances – in terms of robustness with respect to ambiguity problems in the measurement-target association issue - than a set of individual estimators independently built for every probe. Taking into account better estimates obtained, also the guidance phase will offer improved performances.

The design of this descent guidance and navigation subsystem, which is instrumental to the probe swarm mission concept, will be carried out with respect to different dynamical and environmental conditions (velocity and altitude at the descent beginning, presence or lack of atmosphere, relevance of the gravity with respect to perturbing effect) in order to represent the conditions to be faced in different solar system bodies, like Mars, Europa and Titan.