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PROBABILISTIC GUIDANCE OF A SWARM DEPLOYED FROM THE BACK SHELL OF THE MARS SPACECRAFT

Abstract

NASA is considering multiple missions to Mars for a potential Mars Sample Return campaign. At the same time, a number of small assets (e.g., Prandtl-M glider, Tensegrity lander) are being developed to fit in the empty space in the backshell of Mars spacecraft as secondary payloads. These assets could be deployed as secondary payloads after the primary payload has separated from the backshell of Mars spacecraft. We envisage that a swarm of such secondary payloads (100-1000 assets) could be deployed from the backshell of Mars spacecraft for distributed science on Mars. In this paper we present a probabilistic guidance algorithm for such a swarm.

From the science perspective, the key requirement on the swarm distribution would be to maximize its coverage area while staying away from some regions. In addition, the swarm has to maintain a strongly connected communication network topology so that the science data collected by each agent can be sent to Earth via the backshell of Mars spacecraft. These requirements and constraints are captured by a desired swarm distribution on the Martian surface. The objective of our probabilistic swarm algorithm is to determine the release time, angle of deployment, and initial velocity of each asset so that the swarm achieves the desired distribution on the Martian surface, despite the assets being subject to significant environmental disturbances. Moreover, the assets do not have position or attitude sensors and would fall towards the Martian surface in an open-loop manner after being deployed from the Mars spacecraft. This lack of feedback control makes this swarm guidance problem fundamentally different from existing probabilistic swarm guidance algorithms in the literature, which use homogeneous or inhomogeneous Markov chains or optimal transport.

Our probabilistic swarm guidance algorithm captures the transition probabilities from different release times, angles of deployment, and initial velocities to locations on the Martian surface in specially-designed

Markov matrices. Then, our algorithm maximizes the probability of the swarm achieving the desired distribution on the Martian surface while guaranteeing strong-connectivity of the swarm's communication network topology. This novel probabilistic swarm guidance algorithm is the main contribution of this paper. Numerical simulations demonstrate the effectiveness and versatility of our probabilistic swarm guidance algorithm.