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ONBOARD TRAJECTORY GENERATION FOR AUTONOMOUS LANDING ON SMALL BODIES

Abstract

The paper presents a fast trajectory generation algorithm for landing on planetary bodies of different sizes, ranging from asteroids with a few tens of kilometres to moons with a few thousands of kilometres. Past successful landings on small bodies have been mostly performed by following a predetermined trajectory to a nominal landing site, which is usually selected after a long reconnaissance phase of the body. The ability to quickly recompute a landing trajectory onboard provides the ability to change landing site location during flight and handle large disturbances and uncertainties. This is particularly desirable for landing in bodies with unknown and hazardous terrains and uncertain dynamics due to irregular shape and gravity field. The trajectory generation method employed here is based on convex optimization, which guarantees fast convergence to a global optimum (if one exists). Convex optimization has been previously applied to specific problems for landing either on small bodies or planets. The algorithm presented here is formulated in parametric form, having the ability to be applied for a very wide range of bodies and spacecraft models. The algorithm is also developed in a way that can be easily converted into appropriate code to be directly used within an onboard GNC system. Besides the parametric formulation, the program presented here includes two additional features. The first is the possibility to simultaneously optimise the trajectory for both translational and rotational motion of the vehicle. This is particularly important for landing on bodies with hazardous and unknown terrains, where the attitude becomes highly important, as the system includes strict sensor pointing requirements for detection of surface hazards. The second feature is the possibility to optimise the trajectory, along with the number, placement and direction of thrusters. Although this feature cannot be used with the onboard trajectory generation, it is particularly useful for finding an optimal set of thrusters for landing on small bodies, while maintaining the attitude requirements. To demonstrate the ability of the trajectory generation algorithm presented, reference trajectories, along with resulting optimal thruter number and configuration are first presented for both small bodies and larger bodies. Next results from simulation demonstrate the ability for onboard trajectories generation during flight, for cases in which the landing site is changed due to detection of new hazards and for cases presenting large deviations from a nominal trajectory due to unknown environment dynamics.