Paper ID: 68438
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (5)

Author: Ms. Julia Briden
Massachusetts Institute of Technology (MIT), United States, jbriden@mit.edu

Ms. Breanna Johnson
NASA, United States, breanna.j.johnson@nasa.gov
Prof. RICHARD LINARES
Massachusetts Institute of Technology (MIT), United States, linaresr@mit.edu

RISK GUARANTEES FOR INTEGRATED TARGETING AND GUIDANCE DURING POWERED DESCENT AND LANDING

Abstract

During rendezvous and atmospheric entry, descent, and landing (EDL), time constraints make most human interventions infeasible. With the NASA Artemis Program preparing to deliver humans to the lunar surface by 2024, fully autonomous landing technologies are integral to mission readiness. Science missions will require large maneuvers, or diverts, to take a lander to a precise surface location. To ensure these maneuvers are completed with bounded risk, future autonomous descent and targeting systems must account for unexpected disturbances and uncertain sensor data. This paper presents a new online targeting and guidance algorithm for spacecraft powered descent with quantifiable risk.

Current powered descent technologies can compute constraint-satisfying and fuel-optimal diverts but these methods do not include risk-bounded targeting in real-time for the computed trajectories. My work extends state-of-the-art guidance technologies to interface with navigation measurements and develop risk-bounded trajectories. To prove system-level performance guarantees, the technology is implemented on a three degree-of-freedom simulated Human Landing System (HLS) case study. The algorithm uses navigation imagery and measurements to detect all obstacles on the landing site, defines obstacles in a polynomial representation, and uses sum-of-squares optimization to bound the level of allowable risk. Risk bounds are utilized to recompute targeting decisions when the planned landing location is inside of a risk bound. Powered descent trajectory generation uses lossless convexification (LCvx) as the guidance algorithm and includes risk bounds in the set of constraints, to ensure that a large divert will remain robust to sensor uncertainties. The targeting and risk bounding sequence are assessed analytically for time complexity, as well as experimentally, in the HLS case study.

For all test cases, the risk-bounded targeting and guidance algorithm successfully chooses a landing site which is closest to the preferred site and within the bounds of acceptable risk. In addition, the algorithm can be computed online and can be adapted for implementation on flight-grade hardware. The integration of targeting and guidance procedures into an EDL algorithm that is robust to measurement uncertainties has advanced technical developments in the design of intelligent and resilient systems. By providing risk-based guarantees, future missions can pursue scientifically significant targets under uncertain sensor measurements and within potentially hazardous terrains.