Enhanced Fuel-Optimal Trajectory-Generation Algorithm for Planetary Pinpoint Landing

Enhancements are incorporated to allow faster convergence to the fuel optimal solution.

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An enhanced algorithm is developed that builds on a previous innovation of fuel-optimal powered-descent guidance (PDG) for planetary pinpoint landing. The PDG problem is to compute constrained, fuel-optimal trajectories to land a craft at a prescribed target on a planetary surface, starting from a "parachute cut-off" point and using a throttleable descent engine. The previous innovation showed the minimal-fuel PDG problem can be posed as a convex optimization problem, in particular, as a Second-Order Cone Program, which can be solved to global optimality with deterministic convergence properties, and hence is a candidate for onboard implementation. To increase the speed and robustness of this convex PDG algorithm for possible onboard implementation, the following enhancements are incorporated:

- Fast detection of infeasibility (i.e., control authority is not sufficient for soft-landing) for subsequent fault response.
- The use of a piecewise-linear control parameterization, providing smooth solution trajectories and increasing computational efficiency.
- An enhanced line-search algorithm for optimal time-of-flight, providing quicker convergence and bounding the number of path-planning iterations needed.
- An additional constraint that analytically guarantees inter-sample satisfaction of glide-slope and non-sub-surface flight constraints, allowing larger discretizations and, hence, faster optimization.
- Explicit incorporation of Mars rotation rate into the trajectory computation for improved targeting accuracy.

These enhancements allow faster convergence to the fuel-optimal solution and, more importantly, remove the need for a "human-in-the-loop," as constraints will be satisfied over the entire path-planning interval independent of step-size (as opposed to just at the discrete time points) and infeasible initial conditions are immediately detected. Finally, while the PDG stage is typically only a few minutes, ignoring the rotation rate of Mars can introduce 10s of meters of error. By incorporating it, the enhanced PDG algorithm becomes capable of pinpoint targeting.

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