Energy-Time Optimal Path Planning in Strong Dynamic Flows

by

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Abstract

We develop an exact partial differential equation-based methodology that predicts time-energy optimal paths for autonomous vehicles navigating in dynamic environments. The differential equations solve the multi-objective optimization problem of navigating a vehicle autonomously in a dynamic flow field to any destination with the goal of minimizing travel time and energy use. Based on Hamilton-Jacobi theory for reachability and the level set method, the methodology computes the exact Pareto optimal solutions to the multi-objective path planning problem, numerically solving the equations governing time-energy reachability fronts and optimal paths. Our approach is applicable to path planning in various scenarios, however we primarily present examples of navigating in dynamic marine environments. First, we validate the methodology through a benchmark case of crossing a steady front (a highway flow) for which we compare our results to semi-analytical optimal path solutions. We then consider more complex unsteady environments and solve for time-energy optimal missions in a quasi-geostrophic double-gyre ocean flow field.

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