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Navigating unsteady flows: From finite-time Lyapunov exponents to finite-horizon energy-optimal trajectories KARTIK KRISHNA, University of Washington, Seattle, ZHUOYUAN SONG, University of Hawaii at Mnoa, STEVEN BRUNTON, University of Washington, Seattle — Energy-efficient trajectory planning is essential for mobile sensors in adaptive environmental sensing and monitoring arrays. Most active sensing platforms operate in unsteady background flows, such as ocean currents, hurricanes, and windy urban environments. Existing literature has shown that globally energy-efficient paths of mobile sensors tend to utilize the Lagrangian coherent structures (LCS) in unsteady flows. However, the connection between finite-horizon energy-efficient trajectories and LCS remains elusive. To explore this connection, we used a finite-horizon model predictive control algorithm to generate energy-efficient trajectories in a double gyre flow field, which is a canonical model for chaotic mixing in the ocean. In particular, we performed an exhaustive search through optimization hyperparameters, including the prediction time horizon, sampling time, mobility constraints on the sensors velocity relative to the flow, state and control penalty weights, and terminal cost. We uncover a strong connection between the energy spent along a trajectory and the presence of background coherent structures, the presence of periodic orbits around the desired target, and links between the gyre oscillating frequency and the Pareto optimal landscape of the control law.

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