Data-driven olfactory search in a turbulent flow

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Tracking the source of an odor which is advected by a turbulent flow is an important behavior for many flying insects and other animals. This olfactory search problem is rendered especially difficult by the intermittency intrinisic to turbulence, demanding complex search strategies which can leverage the limited information gleaned from sparse, random odor detections.

Recent work[1][2][3] casted this problem into the language of partially observable Markov decision processes (POMDP) and demonstrated that, given a model for the concentration statistics, one can algorithmically solve for policies which are near-optimal with respect to the arrival time to the source. However, this work was performed in toy environments where detections were artificially drawn from the model, rather than in a realistic flow.

In this work, we perform direct numerical simulations (DNS) of the 3-D Navier-Stokes equations with an imposed mean wind in a turbulent regime, while tracking Lagrangian tracer particles emitted from a point source. We study the concentration statistics of the tracer data and use the data to extract model-based policies to search within the DNS flow. We compare the performance, as well as emergent behaviors, of near-optimal policies to those of several heuristics, including infotaxis[4]. We also discuss the robustness of the policies with respect to imperfect models of the environment, and we extend the POMDP to include the effects of short-time correlations.

This work received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 882340).

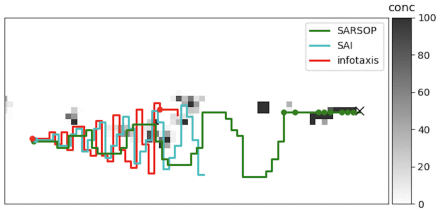

Figure 1: Snapshot of search trajectories obtained using a near-optimal policy (green) and heuristics (cyan and red). The search is performed in concentration data taken from DNS.

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