Using sparse odor cues to infer the location of their source.

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Making sense of turbulence is an interesting and open problem ; living systems evolved the ability to decode information carried by surrounding flows, even in dramatically noisy and intermittent environments [1]. Here I explore how an agent may sense and represent odor to efficiently locate the source. Odor is a complex signal : plumes are detected in isolated pockets, or "whiffs", separated by "blanks", periods where the odor cannot be detected. [2]. Odor signal can be encoded in simpler features based on its intensity (analog features) or on its sparsity (digital features) ; I calculate five features : (A) temporal average of the concentration during whiffs ; (S) peak slope (time derivative of odor upon detection, averaged across whiffs) ; (I) intermittency factor, i.e. time above threshold divided by total sampling time ; (B) average duration of blanks (stretches of time when odor is below detection) ; (W) average duration of whiffs (stretches of time when odor is above threshold).

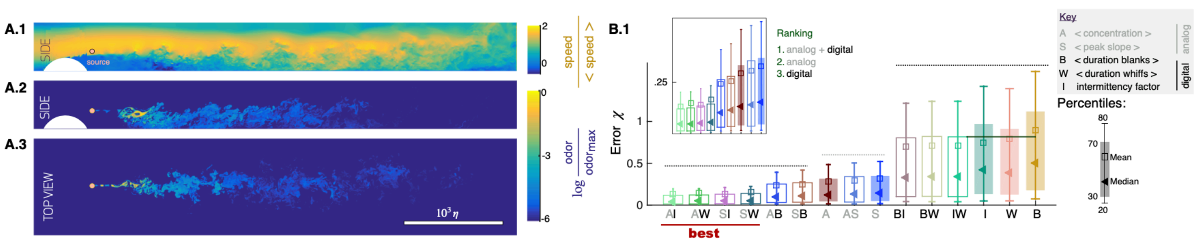

Figure 1. Turbulent odor cues are patchy and intermittent. Snapshot of streamwise velocity (A.1) in a vertical plain at mid channel ; odor snapshot side view at mid channel (A.2) and top view at source height (A.3). Snapshots are obtained from direct numerical simulations of the Navier-Stokes equations and the equation for odor transport. Two classes of features were tested : analogs and digitals. Coupling analog and digital contribution (B.1) offers a better performance than using a single feature or coupling two feature of the same kind.

I use direct numerical simulation (DNS) to generate a turbulent flow in which a realistic odor field spreads from a source (Fig. A). Odor detection occurs within a conical volume, which is the typical shape of the plume. I develop supervised learning algorithms to search for a function $f : x \rightarrow y$, taking odor as input (x) and mapping it into distance from the source (y), algorithm was fed by different quantities (Fig. B). We find that a sparse odor signal can provide robust information about odor source. Odor concentration is a more effective predictor than intermittency for individual datasets ; but intermittency is robust to changes in source intensity and size. Moreover, combining an analogic and a digital feature sensibly improves performance. Different parameters (i.e. detection threshold, sampling frequency, memory, flow sparsity) were varied to make the analysis as broad as possible.

Références

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