Alternation emerges as a multi-modal strategy for turbulent odor navigation

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Foraging mammals often pause to sniff in the air preceded by rearing on their hind legs or raising their head. Interestingly, this behavior emerges spontaneously during olfactory search in presence of airflow, suggesting that alternation may serve an important role during turbulent plume-tracking [1]. To test this hypothesis, we combine fully-resolved numerical simulations of turbulent odor transport and Bellman optimization methods for decision-making under partial observability (POMDP). We show that an agent trained to minimize search time in a realistic odor plume exhibits extensive alternation together with the characteristic cast-and-surge behavior commonly observed in flying insects (see Fig. B). Alternation is tightly linked with casting and occurs more frequently when the agent is far downwind of the source, where the likelihood of detecting airborne cues is higher relative to cues close to the ground. Casting and alternation emerge as complementary tools for effective exploration when cues are sparse. Fluid dynamics explains the alternating behavior, in fact when the environment is turbulent odor cues travel faster and further in the air than at the ground were they are slowed down by the boundary layer. We develop a model based on marginal value theory to capture the interplay between casting, surging and alternation. More generally, we show how multiple sensorimotor modalities can be fruitfully integrated during complex goal-directed behavior. [Preprint on BioRxiv : *https ://www.biorxiv.org/content/10.1101/2021.12.14.472675v1*]

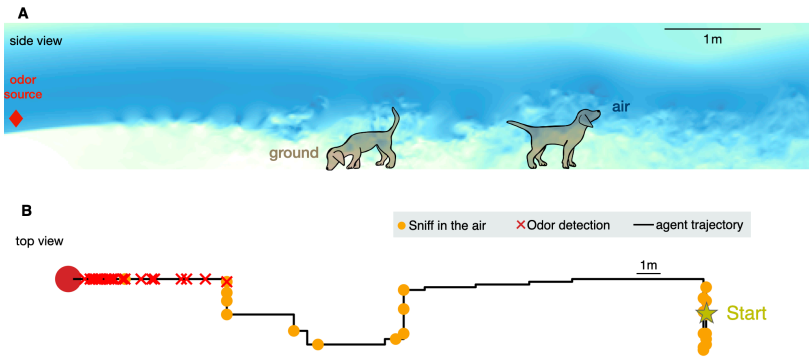

Figure 1. (A) Side view of the direct numerical simulation of odor transport. Shades of blue represent the intensity of velocity fluctuations and are used to visualize the boundary layer near the bottom, where the velocity is reduced by the no-slip condition at the ground. Animals can decide if sniffing the ground or pause and sniff in the air. (B) A representative POMDP trajectory undertaken by an agent learning how to reach the source of a turbulent odor cue at the end of training.

Références

1. DH. Gire & V. Kapoor & A. Arrighi-Allisan & A. Seminara & VN. Murthy, Mice develop efficient strategies for foraging and navigation using complex natural stimuli, *Curr. Biol.*, 26 :1261, (2016).