ANALYZING SINGLE-PARTICLE ANOMALOUS DIFFUSION IN HETEROGENEOUS BIOLOGICAL ENVIRONMENTS

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The super-resolved tracking of single particles undergoing diffusion in a biological environment is a widely used technique that can yield valuable information, either about the diffusing particle itself [1], or about the environment in which the diffusion occurs [2–4]. As an example of the latter, single-walled carbon nanotubes have been used as bright and photostable near-infrared fluorophores to probe the geometry and viscosity of the brain extracellular space [2–4].

In general, diffusion in complex biological environments is anomalous and highly spatially heterogeneous. When extracting quantitative information from a single-particle trajectory, this heterogeneity must be quantified and taken into account. Specifically, we aim at estimating, at each point of the trajectory, the values of the local anomalous exponent and anomalous diffusion coefficient. In our case, these diffusion properties cannot be assumed to jump between a small, finite number of hidden states, contrary to most traditional single-particle tracking analyses [1]; rather, these properties are in fact varying quasi-continuously.

A simple approach consists in splitting a long trajectory into many equal-sized short sub-trajectories that are analyzed separately. We establish that such an approach suffers from large statistical uncertainties, which cannot be distinguished from true variations in diffusive properties. Therefore, we propose an alternate method, which can adaptively and automatically split long trajectories into sub-trajectories that are internally near-homogeneous, without overfitting statistical noise (fig. 1). This method opens up new avenues for the analysis of diffusion in heterogeneous complex environments, as the resulting sub-trajectories can then be further analyzed using the wide variety of models that assume a homogeneous environment.

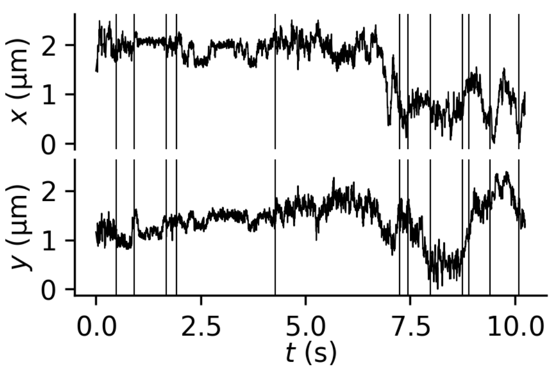

Figure 1: Automatic splitting of a single-particle trajectory into sub-trajectories with constant diffusion properties.

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