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Identification of spatial diffusivity patches by the wavelet processing of single-particle trajectories

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Modern developments in single particle tracking not only open new perspectives for the study of molecular motions in complex environments,
but also allow for using these motions as a probe for revealing properties of substrates on which the motions occur. This approach is
especially important for studying biological membranes since their non-uniform structure (e.g. due to the presence of protein clusters)
results in a large variety of anomalous diffusion phenomena [1]. The first step on this way is providing a map of local
diffusion coefficients. Using a standard approach based on moving time averaging of the local squared displacements poses a task of
judicious choice of the averaging window, which, for achieving satisfactory accuracy, has to be chosen adaptively, depending on the local diffusion coefficient itself.

This complication may be circumvented by generalizing methods of robust linear fitting based on comlexification of the smooth functions
with their subsequent Fourier [2] or Complex Wavelet Transforms (CWT) [3]. For this aim the function $\exp[i\Omega R^2(t)]$,
where $R^2(t)$ is the step-wise displacement squared and Ω is an appropriately chosen factor, is used as an input for the CWT.
A modification with respect to [3] is the replacement of the Morlet wavelet
by a combination of the Tukey window and the multiplicative decomposition of the exponential factor that assures better spatio-temporal localization.

The method proposed was checked in numerical simulations of random walks on patchy structures with different diffusion coefficients within patches,
and was shown to be able to reveal patched structure of diffusion coefficient and to distinguish such situations from random walks with a
time-dependent diffusion coefficient. In addition, the method was applied to the experimental data of [1] provided by courtesy of C. Manzo.
Its application resulted not only in the demonstration of an existence of substrate patches with slowly varying diffusivity but also allowed for a discussion
of a difference between such structures and systems with ergodicity breaking.

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