Journal updates for 2014.06.11

Biophysical Journal (vol. 105, no. 5- vol. 106, no. 11)

Volume 105, Issue 6, 17 September 2013, Pages 1293–1303

Interrogating Biology with Force: Single Molecule High-Resolution Measurements with Optical Tweezers

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Abstract

Single molecule force spectroscopy methods, such as optical and magnetic tweezers and atomic force microscopy, have opened up the possibility to study biological processes regulated by force, dynamics of structural conformations of proteins and nucleic acids, and load-dependent kinetics of molecular interactions. Among the various tools available today, optical tweezers have recently seen great progress in terms of spatial resolution, which now allows the measurement of atomic-scale conformational changes, and temporal resolution, which has reached the limit of the microsecond-scale relaxation times of biological molecules bound to a force probe. Here, we review different strategies and experimental configurations recently developed to apply and measure force using optical tweezers. We present the latest progress that has pushed optical tweezers' spatial and temporal resolution down to today's values, discussing the experimental variables and constraints that are influencing measurement resolution and how these can be optimized depending on the biological molecule under study.

SBA: Good review article for any of us interested in what we might do with the optical trap

Volume 105, Issue 9, 5 November 2013, Pages 2064–2073

Anomalous versus Slowed-Down Brownian Diffusion in the Ligand-Binding Equilibrium

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Abstract

Measurements of protein motion in living cells and membranes consistently report transient anomalous diffusion (subdiffusion) that converges back to a Brownian motion with reduced diffusion coefficient at long times after the anomalous diffusion regime. Therefore, slowed-down Brownian motion could be considered the macroscopic limit of transient anomalous diffusion. On the other hand, membranes are also heterogeneous media in which Brownian motion may be locally slowed down due to variations in lipid composition. Here, we investigate whether both situations lead to a similar behavior for the reversible ligand-binding reaction in two dimensions. We compare the (long-time) equilibrium properties obtained with transient anomalous diffusion due to obstacle hindrance or power-law-distributed residence times (continuous-time random walks) to those obtained with space-dependent slowed-down Brownian motion. Using theoretical arguments and Monte Carlo simulations, we show that these three scenarios have distinctive effects on the apparent affinity of the reaction. Whereas continuous-time random walks decrease the apparent affinity of the reaction, locally slowed-down Brownian motion and local hindrance by obstacles both improve it. However, only in the case of slowed-down Brownian motion is the affinity maximal when the slowdown is restricted to a subregion of the available space. Hence, even at long times (equilibrium), these processes are different and exhibit irreconcilable behaviors when the area fraction of reduced mobility changes.

SBA: Important for Trevor and I as we are considering anomalous diffusion

Volume 105, Issue 12, 17 December 2013, Pages 2641–2654

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Abstract

High-resolution microscopy methods based on different nonlinear optical (NLO) contrast mechanisms are finding numerous applications in biology and medicine. While the basic implementations of these microscopy methods are relatively mature, an important direction of continuing technological innovation lies in improving the throughput of these systems. Throughput improvement is expected to be important for studying fast kinetic processes, for enabling clinical diagnosis and treatment, and for extending the field of image informatics. This review will provide an overview of the fundamental limitations on NLO microscopy throughput. We will further cover several important classes of high-throughput NLO microscope designs with discussions on their strengths and weaknesses and their key biomedical applications. Finally, this review will close with a perspective of potential future technological improvements in this field.

SBA: Mainly for me as I think about how the field is evolving.

Volume 106, Issue 2, 21 January 2014, Pages L09–L11

Discriminating between Anomalous Diffusion and Transient Behavior in Microheterogeneous Environments

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Abstract

Diffusion in macrohomogeneous and microheterogeneous media can be described as effective free diffusion only at sufficiently long times. At intermediate times, the mean-square displacement of a diffusing object shows a transient behavior that can be misinterpreted as anomalous subdiffusion. We discuss how to discriminate between the two.

SBA: Mainly for Trevor and I as we consider anomalous diffusion.

Volume 106, Issue 11, 3 June 2014, Pages 2443–2449

High-Density 3D Single Molecular Analysis Based on Compressed Sensing

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Abstract

Single molecule fitting-based superresolution microscopy achieves sub-diffraction-limit image resolution but suffers from a need for long acquisition times to gather enough molecules. Several methods have recently been developed that analyze high molecule density images but most are only applicable to two dimensions. In this study, we implemented a high-density superresolution localization algorithm based on compressed sensing and a biplane approach that provides three-dimensional information about molecules, achieving super-resolution imaging at higher molecule densities than those achieved using the conventional single molecule fitting method.

SBA: For myself, Trevor, and Yufan due to applications in single molecule imaging and CS.

Proceedings of the National Academy of Sciences, USA (vol. 110, no. 41- vol. 111, no. 23)

vol. 110 no. 41, 16301–16308

Positional information, in bits

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Abstract

Cells in a developing embryo have no direct way of "measuring" their physical position. Through a variety of processes, however, the expression levels of multiple genes come to be correlated with position, and these expression levels thus form a code for "positional information." We show how to measure this information, in bits, using the gap genes in the *Drosophila* embryo as an example. Individual genes carry nearly two bits of information, twice as much as would be expected if the expression patterns consisted only of on/off domains separated by sharp boundaries. Taken together, four gap genes carry enough information to define a cell's location with an error bar of $\sim 1\%$ along the anterior/posterior axis of the embryo. This precision is nearly enough for each cell to have a unique identity, which is the maximum information the system can use, and is nearly constant along the length of the embryo. We argue that this constancy is a signature of optimality in the transmission of information from primary morphogen inputs to the output of the gap gene network.

SBA: Not for anyone in particular; it just seems to be an interesting idea.

February 25, 2014 vol. 111 no. 8, 2931–2936

Lévy flights do not always optimize random blind search for sparse targets

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Abstract

It is generally believed that random search processes based on scale-free, Lévy stable jump length distributions (Lévy flights) optimize the search for sparse targets. Here we show that this popular search advantage is less universal than commonly assumed. We study the efficiency of a minimalist search model based on Lévy flights in the absence and presence of an external drift (underwater current, atmospheric wind, a preference of the walker owing to prior experience, or a general bias in an abstract search space) based on two different optimization criteria with respect to minimal search time and search reliability (cumulative arrival probability). Although Lévy flights turn out to be efficient search processes when the target is far from the starting point, or when relative to the starting point the target is upstream, we show that for close targets and for downstream target positioning regular Brownian motion turns out to be the advantageous search strategy. Contrary to claims that Lévy flights with a critical exponent $\alpha = 1$ are optimal for the search of sparse targets in different settings, based on our optimization parameters the optimal αmay range in the entire interval (1, 2) and especially include Brownian motion as the overall most efficient search strategy.

SBA: Again, mainly for Trevor and myself since we're working on diffusion stuff

April 8, 2014 vol. 111 no. 14 5088–5093

Revealing mesoscopic structural universality with diffusion

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Abstract

Measuring molecular diffusion is widely used for characterizing materials and living organisms noninvasively. This characterization relies on relations between macroscopic diffusion metrics and structure at the mesoscopic scale commensurate with the diffusion length. Establishing such relations remains a fundamental challenge, hindering progress in materials science, porous media, and biomedical imaging. Here we show that the dynamical exponent in the time dependence of the diffusion coefficient distinguishes between the universality classes of the mesoscopic structural complexity. Our approach enables the interpretation of diffusion measurements by objectively selecting and modeling the most relevant structural features. As an example, the specific values of the dynamical exponent allow us to identify the relevant mesoscopic structure affecting MRI-measured water diffusion in muscles and in brain, and to elucidate the structural changes behind the decrease of diffusion coefficient in ischemic stroke.

SBA: Relevant to those of us trying to figure out how to characterize the internal structure of Fn or gels

May 27, 2014 vol. 111 no. 21 7511–7516

Blended particle filters for large-dimensional chaotic dynamical systems

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Abstract

A major challenge in contemporary data science is the development of statistically accurate particle filters to capture non-Gaussian features in large-dimensional chaotic dynamical systems. Blended particle filters that capture non-Gaussian features in an adaptively evolving low-dimensional subspace through particles interacting with evolving Gaussian statistics on the remaining portion of phase space are introduced here. These blended particle filters are constructed in this paper through a mathematical formalism involving conditional Gaussian mixtures combined with statistically nonlinear forecast models compatible with this structure developed recently with high skill for uncertainty quantification. Stringent test cases for filtering involving the 40-dimensional Lorenz 96 model with a 5-dimensional adaptive subspace for nonlinear blended filtering in various turbulent regimes with at least nine positive Lyapunov exponents are used here. These cases demonstrate the high skill of the blended particle filter algorithms in capturing both highly non-Gaussian dynamical features as well as crucial nonlinear statistics for accurate filtering in extreme filtering regimes with sparse infrequent high-quality observations. The formalism developed here is also useful for multiscale filtering of turbulent systems and a simple application is sketched below.

SBA: For Trevor and myself. Perhaps something like this would do better on the logistic map.

Review of Scientific Instruments (vol. 85, no. 4 – vol. 85, no. 5)

Rev. Sci. Instrum. **85**, 045003 (2014)

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A novel dual-stage nanopositioner control framework is presented that considers range constraints. Dual-stage nanopositioners are becoming increasingly popular in applications such as scanning probe microscopy due to their unique ability to achieve long-range and high-speed operation. The proposed control approach addresses the issue that some precision positioning trajectories are not achievable through existing control schemes. Specifically, short-range, low-speed inputs are typically diverted to the long-range actuator, which coincidentally has lower positioning resolution. This approach then limits the dual-stage nanopositioner's ability to achieve the required positioning resolution that is needed in applications where range and frequency are not inversely correlated (which is a typical, but not always the correct assumption for dual stage systems). The proposed range-based control approach is proposed to overcome the limitations of existing control methods. Experimental results show that the proposed control strategy is effective.

SBA: For myself and Jeff, maybe Yufan. Dual stage is becoming all the rage.

IEEE Transactions on Automatic Control (vol. 59, no. 1 – no. 5)

Volume:59 , Issue: 2 , pp. 511-515.

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A nonlinear networked control system is considered in which the measured values are asynchronously sampled and transmitted over multiple communication links. The effects of communication in each link (transmission delay, packet loss and sampling jitter) are captured by a time-varying delay element. A sufficient condition for asymptotic stability of the resulting nonlinear delayed model is provided using the Lyapunov-Krasovskii method. This condition is in the form of a compact linear matrix inequality (LMI) which depends on the amount of communication effects in each link. The results are applied to a robot arm networked control system to show the capabilities of the proposed method. Comparison with the previous works indicates that a considerable improvement in the delay bounds for stability is achieved.

SBA: For myself and Xi. Probably good to think soon about networked nonlinear systems.

Volume:59 , Issue: 5 , pp. 1147-1162

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Optimal sensor scheduling with applications to networked estimation and control systems is considered. We model sensor measurement and transmission instances using jumps between states of a continuous-time Markov chain. We introduce a cost function for this Markov chain as the summation of terms depending on the average sampling frequencies of the subsystems and the effort needed for changing the parameters of the underlying Markov chain. By minimizing this cost function through extending Brockett's recent approach to optimal control of Markov chains, we extract an optimal scheduling policy to fairly allocate the network resources among the control loops. We study the statistical properties of this scheduling policy in order to compute upper bounds for the closed-loop performance of the networked system, where several decoupled scalar subsystems are connected to their corresponding estimator or controller through a shared communication medium. We generalize the estimation results to observable subsystems of arbitrary order. Finally, we illustrate the developed results numerically on a networked system composed of several decoupled water tanks.

SBA: For myself and Xi. An approach to scheduling.

Nano Letters: removed due to low probability of relevant papers

+ one:

Methods and Applications in Fluorescence

Vol. 2, no. 2, 024010 (2014)

Orbital single particle tracking on a commercial confocal microscope using piezoelectric stage feedback

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Single Particle Tracking (SPT) is a technique used to locate fluorescent particles with nanometer precision. In the orbital tracking method the position of a particle is obtained analyzing the distribution of intensity along a circular orbit scanned around the particle. In combination with an active feedback this method allows tracking of particles in 2D and 3D with millisecond temporal resolution. Here we describe a SPT setup based on a feedback approach implemented with minimal modification of a commercially available confocal laser scanning microscope, the Zeiss LSM 510, in combination with an external piezoelectric stage scanner. The commercial microscope offers the advantage of a user-friendly software interface and pre-calibrated hardware components. The use of an external piezo-scanner allows the addition of feedback into the system but also represents a limitation in terms of its mechanical response. We describe in detail this implementation of the orbital tracking method and discuss advantages and limitations. As an example of application to live cell experiments we perform the 3D tracking of acidic vesicles in live polarized epithelial cells.