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Asymptotics of Bayesian error probability and source super-localization in three dimensions

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We present an asymptotic analysis of the minimum probability of error (MPE) in inferring the correct hypothesis in a Bayesian multi-hypothesis testing (MHT) formalism using many pixels of data that are corrupted by signal dependent shot noise, sensor read noise, and background illumination. We perform our analysis for a variety of combined noise and background statistics, including a pseudo-Gaussian distribution that can be employed to treat approximately the photon-counting statistics of signal and background as well as purely Gaussian sensor read-out noise and more general, exponentially peaked distributions. We subsequently evaluate both the exact and asymptotic MPE expressions for the problem of three-dimensional (3D) point source localization. We focus specifically on a recently proposed rotating-PSF imager and compare, using the MPE metric, its 3D localization performance with that of conventional and astigmatic imagers in the presence of background and sensor-noise fluctuations.

Asymptotics of Bayesian error probability and 2D pair superresolution

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This paper employs a recently developed asymptotic Bayesian multi-hypothesis testing (MHT) based error analysis to treat the problem of superresolution imaging of a pair of closely spaced, equally bright point sources. The analysis exploits the notion of the minimum probability of error (MPE) in discriminating between two competing equi-probable hypotheses, a single point source of a certain brightness at the origin vs. a pair of point sources, each of half the brightness of the single source and located symmetrically about the origin, as the distance between the source pair is changed. For a Gaussian point-spread function (PSF), the analysis makes predictions on the scaling of the minimum source strength, expressed in units of photon number, required to disambiguate the pair as a function of their separation in both the signal-dominated and background-dominated regimes. Certain logarithmic corrections to the quartic scaling of the minimum source strength with respect to the degree of superresolution characterize the signal-dominated regime, while the scaling is purely quadratic in the background-dominated regime. For the Gaussian PSF, general results for arbitrary strengths of the signal, background, and sensor noise levels are also presented.

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Designing the focal plane spacing for multifocal plane microscopy

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Multifocal plane microscopy (MUM) has made it possible to study subcellular dynamics in 3D at high temporal and spatial resolution by simultaneously imaging distinct planes within the specimen. MUM allows high accuracy localization of a point source along the z-axis since it overcomes the depth discrimination problem of conventional single plane microscopy. An important question in MUM experiments is how the number of focal planes and their spacings should be chosen to achieve the best possible localization accuracy along the z-axis. Here, we propose approaches based on the Fisher information matrix and report spacing scenarios called strong coupling and weak coupling which yield an appropriate 3D localization accuracy. We examine the effect of numerical aperture, magnification, photon count, emission wavelength and extraneous noise on the spacing scenarios. In addition, we investigate the effect of changing the number of focal planes on the 3D localization accuracy. We also introduce a new software package that provides a user-friendly framework to find appropriate plane spacings for a MUM setup. These developments should assist in optimizing MUM experiments.

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Four-directional stereo-microscopy for 3D particle tracking with real-time error evaluation

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High-speed video stereo-microscopy relies on illumination from two distinct angles to create two views of a sample from different directions. The 3D trajectory of a microscopic object can then be reconstructed using parallax to combine 2D measurements of its position in each image. In this work, we evaluate the accuracy of 3D particle tracking using this technique, by extending the number of views from two to four directions. This allows us to record two independent sets of measurements of the 3D coordinates of tracked objects, and comparison of these enables measurement and minimisation of the tracking error in all dimensions. We demonstrate the method by tracking the motion of an optically trapped microsphere of 5 μm in diameter, and find an accuracy of 2–5 nm laterally, and 5–10 nm axially, representing a relative error of less than 2.5% of its range of motion in each dimension.

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Anomalous diffusion induced by enhancement of memory

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We introduced simple microscopic non-Markovian walk models which describe the underlying mechanism of anomalous diffusions. In the models, we considered the competitions between randomness and memory effects of previous history by introducing the probability parameters. The memory effects were considered in two aspects: one is the perfect memory of whole history and the other is the latest memory enhanced with time. In the perfect memory model super diffusion was induced with the relation of the Hurst exponent H to the controlling parameter p as $H = p$ for $p > 1/2$, while in the latest memory enhancement models, anomalous diffusions involving both super diffusion and sub diffusion were induced with the relations $H = (1 + \alpha)/2$ and $H = (1 - \alpha)/2$ for $0 \leq \alpha \leq 1$, where α is the parameter controlling the degree of the latest memory enhancement. Also we found that, although the latest memory was only considered, the memory improved with time results in the long-range correlations between steps and the correlations increase as time goes on. Thus we suggest the memory enhancement as a key origin describing anomalous diffusions.

Systems and Control Letters

Volume 68

Nothing of interest.

Volume 69

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Volume 70

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Nature Methods

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Objective comparison of particle tracking methods

Jean-Christophe Olivo-Marin and many others

Particle tracking is of key importance for quantitative analysis of intracellular dynamic processes from time-lapse microscopy image data. Because manually detecting and following large numbers of individual particles is not feasible, automated computational methods have been developed for these tasks by many groups. Aiming to perform an objective comparison of methods, we gathered the community and organized an open competition in which participating teams applied their own methods independently to a commonly defined data set including diverse scenarios. Performance was assessed using commonly defined measures. Although no single method performed best across all scenarios, the results revealed clear differences between the various approaches, leading to notable practical conclusions for users and developers.