Optics Express

Volume 23, Issue 4

Determining the rotational mobility of a single molecule from a single image: a numerical study
Adam S. Backer and W. E. Moerner
Stanford University, CA

Measurements of the orientational freedom with which a single molecule may rotate or 'wobble' about a fixed axis have provided researchers invaluable clues about the underlying behavior of a variety of biological systems. In this paper, we propose a measurement and data analysis procedure based on a widefield fluorescence microscope image for quantitatively distinguishing individual molecules that exhibit varying degrees of rotational mobility. Our proposed technique is especially applicable to cases in which the molecule undergoes rotational motions on a timescale much faster than the framerate of the camera used to record fluorescence images. Unlike currently available methods, sophisticated hardware for modulating the polarization of light illuminating the sample is not required. Additional polarization optics may be inserted in the microscope's imaging pathway to achieve superior measurement precision, but are not essential. We present a theoretical analysis, and benchmark our technique with numerical simulations using typical experimental parameters for single-molecule imaging.

Adaptive state observer and PD control for dynamic perturbations in optical systems
H. Gilbergs, H. Fang, K. Frenner, and W. Osten
University of Stuttgart, Germany

High-performance objectives pose strict limitations on residual errors present in the system. External mechanical influences can induce structural vibrations in the optical system which causes a displacement of the lenses present in the system. This will influence the imaging performance, causing degraded images or broadened structures in a lithographic processes. In this paper an adaptive state observer for the detection of structural vibrations of the optical elements of an imaging system based on a series of wavefront tilt measurements is introduced. The observer output is used as an input for a closed-loop PD control to mitigate the lens displacements directly.

Volume 23, Issue 3

Numerical analysis of resolution enhancement in laser scanning microscopy using a radially polarized beam
Yuichi Kozawa and Shunichi Sato
Tohoku University, Japan

The spatial resolution characteristics in confocal laser scanning microscopy (LSM) and two-photon LSM utilizing a higher-order radially polarized Laguerre–Gaussian (RP-LG) beam are numerically analyzed. The size of the point spread function (PSF) and its dependence on the confocal pinhole size are compared with practical LSM using a circularly polarized Gaussian beam on the basis of vector diffraction theory. The spatial frequency response in terms of the optical transfer function (OTF) is also evaluated for LSM using the RP-LG beam. The smaller focal spot characteristics of higher-order RP-LG beams contribute to a dramatic enhancement of the lateral spatial resolution in confocal LSM and two-photon LSM.

Volume 23, Issue 2

Three dimensional multi-molecule tracking in thick samples with extended depth-of-field
Heng Li, Danni Chen, Gaixia Xu, Bin Yu, and Hanben Niu
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We present a non-z-scanning multi-molecule tracking system with nano-resolution in all three dimensions and extended depth of field (DOF), which based on distorted grating (DG) and double-helix point spread function (DH-PSF) combination microscopy (DDCM). The critical component in DDCM is a custom designed composite phase mask (PM) combining the functions of DG and DH-PSF. The localization precision and the effective DOF of the home-built DDCM system based on the designed PM were tested. Our experimental results show that the three-dimensional (3D) localization precision for the three diffraction orders of the grating are $\sigma_{\text{-1st}}(x, y, z) = (6.5\text{ nm}, 9.2\text{ nm}, 23.4\text{ nm})$, $\sigma_{\text{0th}}(x, y, z) = (3.7\text{ nm}, 2.8\text{ nm}, 10.3\text{ nm})$, and $\sigma_{\text{+1st}}(x, y, z) = (5.8\text{ nm}, 6.9\text{ nm}, 18.4\text{ nm})$, respectively. Furthermore, the total effective DOF of the DDCM system is extended to 14 μm. Tracking experiment demonstrated that beads separated over 12 μm along the axial direction at some instants can be localized and tracked successfully.

Physical Review E

Volume 91, Issue 2

Active Brownian particles escaping a channel in single file [with erratum]
Emanuele Locatelli, Fulvio Baldovin, Enzo Orlandini, and Matteo Pierno
University of Padova, Italy

Active particles may happen to be confined in channels so narrow that they cannot overtake each other (single-file conditions). This interesting situation reveals nontrivial physical features as a consequence of the strong interparticle correlations developed in collective rearrangements. We consider a minimal two-dimensional model for active Brownian particles with the aim of studying the modifications introduced by activity with respect to the classical (passive) single-file picture. Depending on whether their motion is dominated by translational or rotational diffusion, we find that active Brownian particles in single file may arrange into clusters that are continuously merging and splitting (active clusters) or merely reproduce passive-motion paradigms, respectively. We show that activity conveys to self-propelled particles a strategic advantage for trespassing narrow channels against external biases (e.g., the gravitational field).

Volume 91, Issue 1

Variational mean-field algorithm for efficient inference in large systems of stochastic differential equations

Michail D. Vrettas, Manfred Opper, and Dan Cornford
University of California, Berkeley, CA

This work introduces a Gaussian variational mean-field approximation for inference in dynamical systems which can be modeled by ordinary stochastic differential equations. This new approach allows one to express the variational free energy as a functional of the marginal moments of the approximating Gaussian process. A restriction of the moment equations to piecewise polynomial functions, over time, dramatically reduces the complexity of approximate inference for stochastic differential equation models and makes it comparable to that of discrete time hidden Markov models. The algorithm is demonstrated on state and parameter estimation for nonlinear problems with up to 1000 dimensional state vectors and compares the results empirically with various well-known inference methodologies.

Systems and Control Letters

Volume 75

Adaptive control design under structured model information limitation: A cost-biased maximum-likelihood approach

Farhad Farokhi, Karl H. Johansson
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Networked control strategies based on limited information about the plant model usually result in worse closed-loop performance than optimal centralized control with full plant model information. Recently, this fact has been established by utilizing the concept of competitive ratio, which is defined as the worst-case ratio of the cost of a control design with limited model information to the cost of the optimal control design with full model information. We show that an adaptive controller, inspired by a controller proposed by Campi and Kumar, with limited plant model information, asymptotically achieves the closed-loop performance of the optimal centralized controller with full model information for almost any plant. Therefore, there exists, at least, one adaptive control design strategy with limited plant model information that can achieve a competitive ratio equal to one. The plant model considered in the paper belongs to a compact set of stochastic linear time-invariant systems and the closed-loop performance measure is the ergodic mean of a quadratic function of the state and control input.

Distributed extremum seeking and formation control for nonholonomic mobile network

Chaoyong Li, Zhihua Qu, Mary Ann Weitnauer
Georgia Institute of Technology, Atlanta, GA

In this paper, an integrated control and optimization problem is studied in the context of formation and coverage of a cluster of nonholonomic mobile robots. In particular, each communication channel is modeled by its outage probability, and hence, connectivity is maintained if the outage probability is less than a certain threshold. The objective of the communication network is to not only maintain resilient communication quality but also extend the network coverage. An information theory based performance index is defined to quantify this control objective. Unlike most of the existing results, the proposed cooperative control design does not assume the knowledge of any gradient (of the performance index). Rather, a distributed extremum seeking algorithm is designed to optimize the connectivity and coverage of the mobile network. The proposed approach retains all the advantages of cooperative control, and it can not only perform extremum seeking individually, but also ensures a consensus of estimates between any pair of connected systems. Simulation results demonstrate effectiveness of the proposed methodology.

Global inverse optimal stabilization of stochastic nonholonomic systems

K.D. Do
Curtin University, Australia

Optimality has not been addressed in existing works on control of (stochastic) nonholonomic systems. This paper presents a design of optimal controllers with respect to a meaningful cost function to globally asymptotically stabilize (in probability) nonholonomic systems affine in stochastic disturbances. The design is based on the Lyapunov direct method, the backstepping technique, and the inverse optimal control design. A class of Lyapunov functions, which are not required to be as nonlinearly strong as quadratic or quartic, is proposed for the control design. Thus, these Lyapunov functions can be applied to design of controllers for underactuated (stochastic) mechanical systems, which are usually required Lyapunov functions of a nonlinearly weak form. The proposed control

design is illustrated on a kinematic cart, of which wheel velocities are perturbed by stochastic noise.

Instability of stochastic switched systems

Hui Zhang and Yuanqing Xia
Beijing Institute of Technology, China

The instability problem of stochastic switched systems is investigated in this paper. Definitions of instability are given in the forms of instability in probability, mth instability, moment exponential instability and almost sure exponential instability. By the aid of Dynkin's formula, Itô's formula and strong law of large numbers, the criteria on instability of stochastic switched systems under arbitrary switching are established based on Lyapunov-like techniques. Simulation examples are presented to illustrate the validity of the results.

Multidimensional Systems and Signal Processing

Volume 17, Issue 1

A stochastic analysis of performance limits for optical microscopes

Sripad Ram, E. Sally Ward, Raimund J. Ober
Texas A&M University

The optical microscope is a powerful instrument for observing cellular events.Recently, the increased use of microscopy in quantitative biological research, including single molecule microscopy, has generated significant interest in determining the performance limits of an optical microscope. Here, we formulate this problem in the context of a parameter estimation approach in which the acquired imaging data is modeled as a spatio-temporal stochastic process. We derive formulations of the Fisher information matrix for models that allow both stationary and moving objects. The effects of background signal, detector size, pixelation and noise sources are also considered. Further, formulations are given that allow the study of defocused objects. Applications are discussed for the special case of the estimation of the location of objects, especially single molecules. Specific emphasis is placed on the derivation of conditions that guarantee block diagonal or diagonal Fisher information matrices.

Journal Review (Feb. 2015)

Automatica

*Automatica seems to have changed its system, that each Volume covers only one month instead of one year.

Predictor based stabilization of neutral type systems with input delay

Vol. 52, Page 125-134

- Vladimir L. Kharitonov
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Abstract

In this contribution we present an extension of the prediction scheme proposed in Manitius and Olbrot (1979) for the compensation of the input delay to the case of linear neutral type systems with input delay. For simplicity of the presentation we treat the case of systems with one state delay.

On the controllability and observability of networked dynamic systems

Vol. 52, Page 63-75

- Tong Zhou[1,]
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Abstract

Some necessary and sufficient conditions are obtained for the controllability and observability of a networked system with linear time invariant (LTI) dynamics. The topology of this system is fixed but arbitrary, and every subsystem is permitted to have different dynamics. These conditions essentially depend only on transmission zeros of every subsystem and the subsystem connection matrix, which makes them attractive in the analysis and synthesis of a large-scale networked system. As an application, these conditions are utilized to characterize systems whose steady estimation accuracy with the distributed predictor of Zhou (2013) is equal to that of the lumped Kalman filter. It has been made clear that to guarantee this equivalence, the steady update gain matrix of the Kalman filter must be block diagonal.

Refined instrumental variable estimation: Maximum likelihood optimization of a unified Box–Jenkins model

Vol. 52, Page 35-46

- Peter C. Young
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- Integrated Catchment Assessment and Management Centre, Australian National University College of Medicine, Biology & Environment, Canberra, ACT, Australia

Abstract

For many years, various methods for the identification and estimation of parameters in linear, discrete-time transfer functions have been available and implemented in widely available Toolboxes for Matlab™. This paper considers a unified *Refined Instrumental Variable* (RIV) approach to the estimation of discrete *and*continuous-time transfer functions characterized by a unified operator that can be interpreted in terms of backward shift, derivative or delta operators. The estimation is based on the formulation of a pseudo-linear regression relationship involving optimal prefilters that is derived from an appropriately unified Box–Jenkins transfer function model. The paper shows that, contrary to apparently widely held beliefs, the iterative RIV algorithm provides a reliable solution to the maximum likelihood optimization equations for this class of Box–Jenkins transfer function models and so its *en bloc* or recursive parameter estimates are optimal in maximum likelihood, prediction error minimization and instrumental variable terms.

Coarsest quantization for networked control of uncertain linear systems

Vol. 52, Page 1-8

- Xile Kang ,
- Hideaki Ishii
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Abstract

In the design of networked control systems, one must take account of communication constraints in the form of data rate. In this paper, we consider a quantized control problem for stabilizing uncertain linear systems in the sense of quadratic stability. For a class of finite-order (possibly time-varying) uncertain autoregressive plants, we show that the coarsest quantizer for achieving quadratic stabilization is of logarithmic type. In particular, for a given quadratic Lyapunov function, the largest coarseness is derived in an analytic form. The result explicitly shows that plants with more uncertainties require more precise information in the quantized signals to achieve quadratic stabilization. We also provide a numerical method based on a linear matrix inequality to search for a Lyapunov function along with a quantizer of a given level of coarseness.

A graph theoretical approach to input design for identification of nonlinear dynamical models

Vol. 51, Page 233-242

- Patricio E. Valenzuela ,
- Cristian R. Rojas ,
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Abstract

In this paper the problem of optimal input design for model identification is studied. The optimal input signal is designed by maximizing a scalar cost function of the information matrix, where the input signal is a realization of a stationary process with finite memory, with its range being a finite set of values. It is shown that the feasible set for this problem can be associated with the prime cycles in the graph of possible values and transitions for the input signal. A realization of the optimal input signal is generated by running a Markov chain associated with the feasible set, where the transition matrix is built using a novel algorithm developed for de Bruijn graphs. The proposed method can be used to design inputs for nonlinear output-error systems, which are not covered in previous results. In particular, since the input is restricted to a finite alphabet, it can naturally handle amplitude constraints. Finally, our approach relies on convex optimization even for systems having a nonlinear structure. A numerical example shows that the algorithm can be successfully used to perform input design for nonlinear output-error models.

Dynamic coupling design for nonlinear output agreement and time-varying flow control

Vol. 51, Page 210-222

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Abstract
This paper studies the problem of output agreement in networks of nonlinear dynamical systems under time-varying disturbances, using dynamic diffusive couplings. Necessary conditions are derived for general networks of nonlinear systems, and these conditions are explicitly interpreted as conditions relating the node dynamics and the network topology. For the class of incrementally passive systems, necessary and sufficient conditions for output agreement are derived. The approach proposed in the paper lends itself to solve flow control problems in distribution networks. As a first case study, the internal model approach is used for designing a controller that achieves an optimal routing and inventory balancing in a dynamic transportation network with storage and time-varying supply and demand. It is in particular shown that the time-varying optimal routing problem can be solved by applying an internal model controller to the dual variables of a certain convex network optimization problem. As a second case study, we show that droop-controllers in microgrids have also an interpretation as internal model controllers.

Mechatronics

A neural network based technique for vibration characterization using Gaussian laser beams

Vol. 25, Page 44-54

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Abstract
This paper presents a neural network technique combined with an optical measurement system for the characterization of mechanical vibrations in industrial machinery. In the proposed system, the Gaussian beam of a laser source illuminates on an array of photodetectors. If either the laser source or the photodetector array is coupled with a vibrating system, then the optical powers detected by the photodetectors will vary accordingly, and are expected to reflect the magnitude and frequency of the X–Y planar vibrations of the monitored system. The time-varying optical powers are input to an artificial neural network-based vibration monitoring system which maps the power distributions to the X–Y position of the laser beam center. An experimental setup of the system is built and used for training and testing purposes. The obtained experimental results demonstrate the adequacy of combining optical techniques with neural networks to estimate the vibration frequency and magnitude. Estimated frequencies were within 1% of the actual ones, and the estimated magnitudes were within 29% of the actual magnitudes when using a chirp signal in the training phase. The magnitude estimation percentage error was further reduced below 12% when the neural network was trained with a decaying chirp signal.

IEEE T-Ro

Multirobot Rendezvous Planning for Recharging in Persistent Tasks

Vol. 31, Issue 1, Page 128-142

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Smith, S.L. ; Waslander, S.L.

Abstract
This paper addresses a multirobot scheduling problem in which autonomous unmanned aerial vehicles (UAVs) must be recharged during a long-term mission. The proposal is to introduce a separate team of dedicated charging robots that the UAVs can dock with in order to recharge. The goal is to schedule and plan minimum cost paths for charging robots such that they rendezvous with and replenish the UAVs, as needed, during the mission. The approach is to discretize the 3-D UAV flight trajectories into sets of projected charging points on the ground, thus allowing the problem to be abstracted onto a partitioned graph. Solutions consist of charging robot paths that collectively charge each of the UAVs. The problem is solved by first formulating the rendezvous planning problem to recharge each UAV once using both an integer linear program and a transformation to the Travelling Salesman Problem. The methods are then leveraged to plan recurring rendezvous' over longer horizons using fixed horizon and receding horizon strategies. Simulation results using realistic vehicle and battery models demonstrate the feasibility and robustness of the proposed approach.

High-Frequency Replanning Under Uncertainty Using Parallel Sampling-Based Motion Planning

Vol. 31, Issue 1, Page 104-116

Sun, W.
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Patil, S. ; Alterovitz, R.

Abstract
As sampling-based motion planners become faster, they can be reexecuted more frequently by a robot during task execution to react to uncertainty in robot motion, obstacle motion, sensing noise, and uncertainty in the robot's kinematic model. We investigate and analyze high-frequency replanning (HFR) where, during each period, fast sampling-based motion planners are executed in parallel as the robot simultaneously executes the first action of the best motion plan from the previous period. We consider discrete-time systems with stochastic nonlinear (but linearizable) dynamics and observation models with noise drawn from zero mean Gaussian distributions. The objective is to maximize the probability of success (i.e., avoid collision with obstacles and reach the goal) or to minimize path length subject to a lower bound on the probability of success. We show that, as parallel computation power increases, HFR offers asymptotic optimality for these objectives during each period for goal-oriented problems. We then demonstrate the effectiveness of HFR for holonomic and nonholonomic robots including car-like vehicles and steerable medical needles.

Provably-Good Distributed Algorithm for Constrained Multi-Robot Task Assignment for Grouped Tasks

Vol. 31, Issue 1, Page 19-30

Luo, L.
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Chakraborty, N. ; Sycara, K.

Abstract
In this paper, we present provably-good distributed task assignment algorithms for a heterogeneous multi-robot system, in which the tasks form disjoint groups and there are constraints on the number of tasks a robot can do (both within the overall mission and within each task group). Each robot obtains a payoff (or incurs a cost) for each task and the overall objective for task allocation is to maximize (minimize) the total payoff (cost) of the robots. In general, existing algorithms for task allocation either assume that tasks are independent or do not provide performance guarantee for the situation, in which task constraints exist. We present a distributed algorithm to provide an almost optimal solution for our problem. The key aspect of our distributed algorithm is that the overall objective is (almost) maximized by each robot maximizing its own objective iteratively (using a modified payoff function based on an auxiliary variable, called price of a task). Our distributed algorithm is polynomial in the number of tasks, as well as the number of robots.

Controlling Rigid Formations of Mobile Agents Under Inconsistent Measurements

Vol. 31, Issue 1, Page 31-39

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Cao, M. ; Jayawardhana, B.

Abstract
Despite the great success of using gradient-based controllers to stabilize rigid formations of autonomous agents in the past years, surprising yet intriguing undesirable collective motions have been reported recently, when inconsistent measurements are used in the agents' local controllers. To make the existing gradient control robust against such measurement inconsistency, we exploit local estimators following the well-known internal model principle for robust output regulation control. The new estimator-based gradient control is still distributed in nature, and can be constructed systematically even when the number of agents in a rigid formation grows. We prove rigorously that the proposed control is able to guarantee exponential convergence, and then demonstrate through robotic experiments and computer simulations that the reported inconsistency-induced orbits of collective movements are effectively eliminated.

Journal updates for 2015.02.27

Biophysical Journal

(vol. 107, no. 9)

Localization Precision in Stepwise Photobleaching Experiments

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The precise determination of the position of fluorescent labels is essential for the quantitative study of biomolecular structures by various localization microscopy techniques. Localization by stepwise photobleaching is especially suited for measuring nanometer-scale distances between two labels; however, the precision of this method has remained elusive. Here, we show that shot noise from other emitters and error propagation compromise the localization precision in stepwise photobleaching. Incorporation of point spread function-shaped shot noise into the variance term in the Fisher matrix yielded fundamental Cràmer-Rao lower bounds (CRLBs) that were in general anisotropic and depended on emitter intensity and position. We performed simulations to benchmark the extent to which different analysis procedures reached these ideal CRLBs. The accumulation of noise from several images accounted for the worse localization precision in image subtraction. Propagation of fitting errors compromised the CRLBs in sequential fitting using fixed parameters. Global fitting of all images was also governed by error propagation, but made optimal use of the available information. The precision of individual distance measurements depended critically on the exact bleaching kinetics and was correctly quantified by the CRLBs. The methods presented here provide a consistent framework for quantitatively analyzing stepwise photobleaching experiments and shed light on the localization precision in some other bleaching- or blinking-assisted techniques.

SBA: Interesting to note that it is clearly accepted by the community that simulation-based analyses are good explorations.

(vol. 107, no. 10)

Identifying Transport Behavior of Single-Molecule Trajectories

Benjamin M. Regner, Daniel M. Tartakovsky, Terrence J. Sejnowski
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Models of biological diffusion-reaction systems require accurate classification of the underlying diffusive dynamics (e.g., Fickian, subdiffusive, or superdiffusive). We use a renormalization group operator to identify the anomalous (non-Fickian) diffusion behavior from a short trajectory of a single molecule. The method provides quantitative information about the underlying stochastic process, including its anomalous scaling exponent. The classification algorithm is first validated on simulated trajectories of known scaling. Then it is applied to experimental trajectories of microspheres diffusing in cytoplasm, revealing heterogeneous diffusive dynamics. The simplicity and robustness of this classification algorithm makes it an effective tool for analysis of rare stochastic events that occur in complex biological systems.

(vol. 107, no. 11)

Nothing of interest.

(vol. 107, no. 12)

Mapping Diffusion in a Living Cell via the Phasor Approach

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Diffusion of a fluorescent protein within a cell has been measured using either fluctuation-based techniques (fluorescence correlation spectroscopy (FCS) or raster-scan image correlation spectroscopy) or particle tracking. However, none of these methods enables us to measure the diffusion of the fluorescent particle at each pixel of the image. Measurement using conventional single-point FCS at every individual pixel results in continuous long exposure of the cell to the laser and eventual bleaching of the sample. To overcome this limitation, we have developed what we believe to be a new method of scanning with simultaneous construction of a fluorescent image of the cell. In this believed new method of modified raster scanning, as it acquires the image, the laser scans each individual line multiple times before moving to the next line. This continues until the entire area is scanned. This is different from the original raster-scan image correlation spectroscopy approach, where data are acquired by scanning each frame once and then scanning the image multiple times. The total time of data acquisition needed for this method is much shorter than the time required for traditional FCS analysis at each pixel. However, at a single pixel, the acquired intensity time sequence is short; requiring nonconventional analysis of the correlation function to extract information about the diffusion. These correlation data have been analyzed using the phasor approach, a fit-free method that was originally developed for analysis of FLIM images. Analysis using this method results in an estimation of the average diffusion coefficient of the fluorescent species at each pixel of an image, and thus, a detailed diffusion map of the cell can be created.

(vol. 108, no. 1,2)
Nothing of interest

(vol. 108, no. 3)

Particle Transport through Hydrogels Is Charge Asymmetric

Xiaolu Zhang, Johann Hansing, Roland R. Netz, Jason E. DeRouchey
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Transport processes within biological polymer networks, including mucus and the extracellular matrix, play an important role in the human body, where they serve as a filter for the exchange of molecules and nanoparticles. Such polymer networks are complex and heterogeneous hydrogel environments that regulate diffusive processes through finely tuned particle-network interactions. In this work, we present experimental and theoretical studies to examine the role of electrostatics on the basic mechanisms governing the diffusion of charged probe molecules inside model polymer networks. Translational diffusion coefficients are determined by fluorescence correlation spectroscopy measurements for probe molecules in uncharged as well as cationic and anionic polymer solutions. We show that particle transport in the charged hydrogels is highly asymmetric, with diffusion slowed down much more by electrostatic attraction than by repulsion, and that the filtering capability of the gel is sensitive to the solution ionic strength. Brownian dynamics simulations of a simple model are used to examine key parameters, including interaction strength and interaction range within the model networks. Simulations, which are in quantitative agreement with our experiments, reveal the charge asymmetry to be due to the sticking of particles at the vertices of the oppositely charged polymer networks.

Multifocal Fluorescence Microscope for Fast Optical Recordings of Neuronal Action Potentials

Matthew Shtrahman, Daniel B. Aharoni, Nicholas F. Hardy, Dean V. Buonomano, Katsushi Arisaka, Thomas S. Otis
UCLA

In recent years, optical sensors for tracking neural activity have been developed and offer great utility. However, developing microscopy techniques that have several kHz bandwidth necessary to reliably capture optically reported action potentials (APs) at multiple locations in parallel remains a significant challenge. To our knowledge, we describe a novel microscope optimized to measure spatially distributed optical signals with submillisecond and near diffraction-limit resolution. Our design uses a spatial light modulator to generate patterned illumination to simultaneously excite multiple user-defined targets. A galvanometer driven mirror in the emission path streaks the fluorescence emanating from each excitation point during the camera exposure, using unused camera pixels to capture time varying fluorescence at rates that are ~1000 times faster than the camera's native frame rate. We demonstrate that this approach is capable of recording $Ca2+$ transients resulting from APs in neurons labeled with the $Ca2+$ sensor Oregon Green Bapta-1 (OGB-1), and can localize the timing of these events with millisecond resolution. Furthermore, optically reported APs can be detected with the voltage sensitive dye DiO-DPA in multiple locations within a neuron with a signal/noise ratio up to ~40, resolving delays in arrival time along dendrites. Thus, the microscope provides a powerful tool for photometric measurements of dynamics requiring submillisecond sampling at multiple locations.

Analyzing Single-Molecule Time Series via Nonparametric Bayesian Inference

Keegan E. Hines, John R. Bankston, Richard W. Aldrich
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The ability to measure the properties of proteins at the single-molecule level offers an unparalleled glimpse into biological systems at the molecular scale. The interpretation of single-molecule time series has often been rooted in statistical mechanics and the theory of Markov processes. While existing analysis methods have been useful, they are not without significant limitations including problems of model selection and parameter nonidentifiability. To address these challenges, we introduce the use of nonparametric Bayesian inference for the analysis of single-molecule time series. These methods provide a flexible way to extract structure from data instead of assuming models beforehand. We demonstrate these methods with applications to several diverse settings in single-molecule biophysics. This approach provides a well-constrained and rigorously grounded method for determining the number of biophysical states underlying single-molecule data.

Vol. 108, no. 4

Nothing of interest.

Proceedings of the National Academy of Sciences, USA

(vol 111, no. 43,44,45,46,47,48,49,50,51,52)

Nothing of interest.

(vol. 112, no. 1,2,3,4,5,6,7)

Nothing of interest.

Review of Scientific Instruments

(vol. 85, no. 10)

Adaptive AFM scan speed control for high aspect ratio fast structure tracking

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Improved imaging rates in Atomic Force Microscopes (AFM) are of high interest for disciplines such as life sciences and failure analysis of semiconductor wafers, where the sample topology shows high aspect ratios. Also, fast imaging is necessary to cover a large surface under investigation in reasonable times.
Since AFMs are composed of mechanical components, they are associated with comparably low resonance frequencies that undermine the effort to increase the acquisition rates. In particular, high and steep structures are difficult to follow, which causes the cantilever to temporarily loose contact to or crash into the sample. Here, we report on a novel approach that does not affect the scanner dynamics, but adapts the lateral scanning speed of thescanner. The controller monitors the control error signal and, only when necessary, decreases the scan speed to allow the z-piezo more time to react to changes in the sample's topography. In this case, the overall imaging rate can be significantly increased, because a general scan speed trade-off decision is not needed and smooth areas are scanned fast. In contrast to methods trying to increase the z-piezo bandwidth, our method is a comparably simple approach that can be easily adapted to standard systems.

(vol. 85, no. 11,12, vol. 86, no. 1)

Nothing of interest.

IEEE Transactions on Automatic Control

(vol 59, no. 12, vol. 60, no. 1, no. 2)

Nothing of interest.

+ one:

IEEE Trans. on Signal Processing, vol. 57, no. 2, pp. 463-470, 2009.

An EM Algorithm for Markov Modulated Markov Processes

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An expectation-maximization (EM) algorithm for estimating the parameter of a Markov modulated Markov process in the maximum likelihood sense is developed. This is a doubly stochastic random process with an underlying continuous-time finite-state homogeneous Markov chain. Conditioned on that chain, the observable process is a continuous-time finite-state nonhomogeneous Markov chain. The generator of the observable process at any given time is determined by the state of the underlying Markov chain at that time. The parameter of the process comprises the set of generators for the underlying and conditional Markov chains. The proposed approach generalizes an earlier approach by Ryden for estimating the parameter of a Markov modulated Poisson process.

IEEE Transactions on Signal Processing (Issue 4, 5, 6, 2015)
IEEE/ASME Transactions on Mechatronics (Issue 1, 2015)

Bayesian Multi-Target Tracking With Merged Measurements Using Labelled Random Finite Sets

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Curtin University, Australia

Abstract

Most tracking algorithms in the literature assume that the targets always generate measurements independently of each other, i.e., the sensor is assumed to have infinite resolution. Such algorithms have been dominant because addressing the presence of merged measurements increases the computational complexity of the tracking problem, and limitations on computing resources often make this infeasible. When merging occurs, these algorithms suffer degraded performance, often due to tracks being terminated too early. In this paper, we use the theory of random finite sets (RFS) to develop a principled Bayesian solution to tracking an unknown and variable number of targets in the presence of merged measurements. We propose two tractable implementations of the resulting filter, with differing computational requirements. The performance of these algorithms is demonstrated by Monte Carlo simulations of a multi-target bearings-only scenario, where measurements become merged due to the effect of finite sensor resolution.

Target Tracking via Crowdsourcing: A Mechanism Design Approach

Nianxia Cao, Swastik Brahma, Pramod K. Varshney
Syracuse University

Abstract

In this paper, we propose a crowdsourcing-based framework for myopic target tracking by designing an optimal incentive-compatible mechanism in a wireless sensor network (WSN) containing sensors that are selfish and profit-motivated. In typical WSNs which have limited bandwidth, the fusion center (FC) has to distribute the total number of bits that can be transmitted from the sensors to the FC among the sensors. In the formulation considered here, the FC conducts an auction by soliciting bids from the selfish sensors, which reflect how much they value their energy cost. Furthermore, the rationality and truthfulness of the sensors are guaranteed in our model. The final problem is formulated as a multiple-choice knapsack problem (MCKP), which is solved by the dynamic programming method in pseudo-polynomial time. Simulation results show the effectiveness of our proposed approach in terms of both the tracking performance and lifetime of the sensor network.

Alternating Optimization of Sensing Matrix and Sparsifying Dictionary for Compressed Sensing

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Abstract

This paper deals with alternating optimization of sensing matrix and sparsifying dictionary for compressed sensing systems. Under the same framework proposed by J. M. Duarte-Carvajalino and G. Sapiro, a novel algorithm for optimal sparsifying dictionary design is derived with an optimized sensing matrix embedded. A closed-form solution to the optimal dictionary design problem is obtained. A new measure is proposed for optimizing sensing matrix and an algorithm is developed for solving the corresponding optimization problem. Experiments are carried out with synthetic data and real images, which demonstrate promising performance of the proposed algorithms and superiority of the CS system designed with the optimized sensing matrix and dictionary to existing ones in terms of signal reconstruction accuracy. Particularly, the proposed CS system yields in general a much improved performance than those designed using previous methods in terms of peak signal-to-noise ratio for the application to image compression.

Deterministic Constructions of Binary Measurement Matrices From Finite Geometry

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Abstract
Deterministic constructions of measurement matrices in compressed sensing (CS) are considered in this paper. The constructions are inspired by the recent discovery of Dimakis, Smarandache and Vontobel which says that parity-check matrices of good low-density parity-check (LDPC) codes can be used as provably good measurement matrices for compressed sensing under l_1-minimization. The performance of the proposed binary measurement matrices is mainly theoretically analyzed with the help of the analyzing methods and results from (finite geometry) LDPC codes. Particularly, several lower bounds of the spark (i.e., the smallest number of columns that are linearly dependent, which totally characterizes the recovery performance of -minimization) of general binary matrices and finite geometry matrices are obtained and they improve the previously known results in most cases. Simulation results show that the proposed matrices perform comparably to, sometimes even better than, the corresponding Gaussian random matrices. Moreover, the proposed matrices are sparse, binary, and most of them have cyclic or quasi-cyclic structure, which will make the hardware realization convenient and easy.

Matching Pursuit LASSO Part I: Sparse Recovery Over Big Dictionary

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Abstract
Large-scale sparse recovery (SR) by solving l_1-norm relaxations over Big Dictionary is a very challenging task. Plenty of greedy methods have therefore been proposed to address big SR problems, but most of them require restricted conditions for the convergence. Moreover, it is non-trivial for them to incorporate the l_1-norm regularization that is required for robust signal recovery. We address these issues in this paper by proposing a Matching Pursuit LASSO (MPL) algorithm, based on a novel quadratically constrained linear program (QCLP) formulation, which has several advantages over existing methods. Firstly, it is guaranteed to converge to a global solution. Secondly, it greatly reduces the computation cost of the l_1-norm methods over Big Dictionaries. Lastly, the exact sparse recovery condition of MPL is also investigated.

Recursive Maximum Likelihood Identification of Jump Markov Nonlinear Systems

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Abstract
We present an online method for joint state and parameter estimation in jump Markov non-linear systems (JMNLS). State inference is enabled via the use of particle filters which makes the method applicable to a wide range of non-linear models. To exploit the inherent structure of JMNLS, we design a Rao-Blackwellized particle filter (RBPF) where the discrete mode is marginalized out analytically. This results in an efficient implementa-

tion of the algorithm and reduces the estimation error variance. The proposed RBPF is then used to compute, recursively in time, smoothed estimates of complete data sufficient statistics. Together with the online expectation maximization algorithm, this enables recursive identification of unknown model parameters including the transition probability matrix. The method is also applicable to online identification of jump Markov linear systems(JMLS). The performance of the method is illustrated in simulations and on a localization problem in wireless networks using real data.

Performance of Sinusoidal Scanning With MPC in AFM Imaging

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Abstract

An atomic force microscope (AFM) is an extremely versatile investigative tool in the field of nanotechnology, the performance of which is significantly influenced by its conventional zig-zag raster pattern scanning method. In this paper, in order to increase its imaging speed, we consider the use of a sinusoidal scanning method, i.e., a spiral scanning method with an improved model predictive control (MPC) scheme. In this approach, spirals are generated by applying waves, each with a single frequency and slowly varying amplitude, in the X-piezo (sine wave) and Y-piezo (cosine wave) of the piezoelectric tube scanner (PTS) of the AFM. As these input signals are single frequencies, the scanning can proceed faster than traditional raster scanning, without exciting the resonant mode of the PTS. The proposed MPC controller reduces the phase error between the reference position input and measured output sinusoids and provides better tracking of the reference signal. Also, a notch filter is designed and included in the feedback loop to suppress vibrations of the PTS at the resonant frequency. The experimental results show that, using the proposed method, the AFM is able to scan a 6 μm radius image within 2.04 s with a quality better than that obtained using the conventional raster pattern scanning method.

Plus One

LDPC Codes for Compressed Sensing

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Abstract

We present a mathematical connection between channel coding and compressed sensing. In particular, we link, on the one hand, channel coding linear programming decoding (CCLPD), which is a well-known relaxation of maximum-likelihood channel decoding for binary linear codes, and, on the other hand, compressed sensing linear programming decoding (CS-LPD), also known as basis pursuit, which is a widely used linear programming relaxation for the problem of finding the sparsest solution of an under-determined system of linear equations. More specifically, we establish a tight connection between CS-LPD based on a zero-one measurement matrix over the reals and CC-LPD of the binary linear channel code that is obtained by viewing this measurement matrix as a binary parity-check matrix. This connection allows the translation of performance guarantees from one setup to the other. The main message of this paper is that parity-check matrices of good channel codes can be used as provably good measurement matrices under basis pursuit. In particular, we provide the first deterministic construction of compressed sensing measurement matrices with an order-optimal number of rows using high-girth low-density parity-check (LDPC) codes constructed by Gallager.
