Biophysical Journal

Vol. 108, no. 7,8
Nothing of interest.

Proceedings of the National Academy of Sciences, USA
(vol. 112, no. 14,15,16,17)
Nothing of interest.

Review of Scientific Instruments
(vol. 86, no. 4)

Model based control of dynamic atomic force microscope
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A model-based robust control approach is proposed that significantly improves imaging bandwidth for the dynamic mode atomic force microscopy. A model for cantilever oscillation amplitude and phase dynamics is derived and used for the control design. In particular, the control design is based on a linearized model and robust $H_{\infty}$ control theory. This design yields a significant improvement when compared to the conventional proportional-integral designs and verified by experiments.

Multi-Agent Deployment in 3-D via PDE Control
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UC San Diego

This paper introduces a methodology for modelling, analysis, and control design of a large-scale system of agents deployed in 3-D space. The agents' communication graph is a mesh-grid disk 2-D topology in polar coordinates. Treating the agents as a continuum, we model the agents' collective dynamics by complex-valued reaction-diffusion 2-D partial differential equations (PDEs) in polar coordinates, whose states represent the position coordinates of the agents. Due to the reaction term in the
PDEs, the agents can achieve a rich family of 2-D deployment manifolds in 3-D space which correspond to the PDEs' equilibrium as determined by the boundary conditions. Unfortunately, many of these deployment surfaces are open-loop unstable. To stabilize them, a heretofore open and challenging problem of PDE stabilization by boundary control on a disk has been solved in this paper, using a new class of explicit backstepping kernels that involve the Poisson kernel. A dual observer, which is also explicit, allows to estimate the positions of all the agents, as needed in the leaders' feedback, by only measuring the position of their closest neighbors. Hence, an all-explicit control scheme is found which is distributed in the sense that each agent only needs local information. Closed-loop exponential stability in the $L^2$, $H^1$, and $H^2$ spaces is proved for both full state and output feedback designs. Numerical simulations illustrate the proposed approach for 3-D deployment of discrete agents.

(vol. 60, no. 5)
Nothing of interest.

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IEEE Signal Processing Magazine, vol. 32, no. 1


Ram Ober, A. Tahmasbi, S. Ram, Z. Lin, E.S. Ward

Single-molecule microscopy is a relatively new optical microscopy technique that allows the detection of individual molecules such as proteins in a cellular context. This technique has generated significant interest among biologists, biophysicists, and biochemists, as it holds the promise to provide novel insights into subcellular processes and structures that otherwise cannot be gained through traditional experimental approaches. Single-molecule experiments place stringent demands on experimental and algorithmic tools due to the low signal levels and the presence of significant extraneous noise sources. Consequently, this has necessitated the use of advanced statistical signal- and image-processing techniques for the design and analysis of single-molecule experiments. In this tutorial article, we provide an overview of single-molecule microscopy from early works to current applications and challenges. Specific emphasis will be on the quantitative aspects of this imaging modality, in particular single-molecule localization and resolvability, which will be discussed from an information-theoretic perspective. We review the stochastic framework for image formation, different types of estimation techniques, and expressions for the Fisher information matrix. We also discuss several open problems in the field that demand highly nontrivial signal processing algorithms.
Adaptive Search and Tracking of Sparse Dynamic Targets Under Resource Constraints
Gregory Newstadt, Dennis Wei, and Alfred O. Hero
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Abstract
This paper considers the problem of resource-constrained and noise-limited localization and estimation of dynamic targets that are sparsely distributed over a large area. We generalize an existing framework [Bashan, 2008] for adaptive allocation of sensing resources to the dynamic case, accounting for time-varying target behavior such as transitions to neighboring cells and varying amplitudes over a potentially long time horizon. The proposed adaptive sensing policy is driven by minimization of a surrogate function for mean squared error within locations containing targets. We provide theoretical upper bounds on the performance of adaptive sensing policies by analyzing solutions with oracle knowledge of target locations, gaining insight into the effect of target motion and amplitude variation as well as sparsity. Exact minimization of the multistage objective function is infeasible, but myopic optimization yields a closed-form solution. We propose a simple non-myopic extension, the Dynamic Adaptive Resource Allocation Policy (D-ARAP), that allocates a fraction of resources for exploring all locations rather than solely exploiting the current belief state. Our numerical studies indicate that D-ARAP has the following advantages: (a) it is more robust than the myopic policy to noise, missing data, and model mismatch; (b) it performs comparably to well-known approximate dynamic programming solutions but at significantly lower computational complexity; and (c) it improves greatly upon nonadaptive uniform resource allocation in terms of estimation error and probability of detection.

Measure of Nonlinearity for Estimation
Yu Liu and X. Rong Li
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Abstract
Nonlinearity, among other factors, is often the root cause of difficulties in nonlinear problems. It is important to quantify a problem’s degree of nonlinearity to decide a proper solution. For example, a full-blown nonlinear filter is needed in general if the estimation problem is highly nonlinear, but a quasi-linear filter (e.g., an extended Kalman filter) is sufficient for a weakly nonlinear case. This paper first surveys various measures of nonlinearity (MoNs) for different applications. For nonlinear estimation, we conclude that these MoNs are not suitable and a better measure is needed. In view of this, we propose a general MoN for estimation. It measures the mean-square closeness between a point and a subspace in a functional space. Properties and computation of this measure are studied. Numerical examples of static models for parameter estimation and dynamic models for process estimation are given to illustrate our measure.

$l_0$ Sparsifying Transform Learning With Efficient Optimal Updates and Convergence Guarantees
Saiprasad Ravishankar, Yoram Bresler
UIUC
Abstract
Many applications in signal processing benefit from the sparsity of signals in a certain transform domain or
dictionary. Synthesis sparsifying dictionaries that are directly adapted to data have been popular in applica-
tions such as image denoising, inpainting, and medical image reconstruction. In this paper, we focus instead
on the sparsifying transform model, and study the learning of well-conditioned square sparsifying transforms.
The proposed algorithms alternate between a $l_0$ norm-based sparse coding step, and a non-convex transform
update step. We derive the exact analytical solution for each of these steps. The proposed solution for the
transform update step achieves the global minimum in that step, and also provides speedups over iterative
solutions involving conjugate gradients. We establish that our alternating algorithms are globally convergent
to the set of local minimizers of the nonconvex transform learning problems. In practice, the algorithms are
insensitive to initialization. We present results illustrating the promising performance and significant speed-ups
of transform learning over synthesis K-SVD in image denoising.

Low-Complexity Multiclass Encryption by Compressed Sensing
Cambrereri, V., Mangia, M., Pareschi, F., Rovatti, R., Setti, G.
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Abstract
The idea that compressed sensing may be used to encrypt information from unauthorized receivers has already
been envisioned but never explored in depth since its security may seem compromised by the linearity of its
encoding process. In this paper, we apply this simple encoding to define a general private-key encryption scheme
in which a transmitter distributes the same encoded measurements to receivers of different classes, which are
provided partially corrupted encoding matrices and are thus allowed to decode the acquired signal at provably
different levels of recovery quality. The security properties of this scheme are thoroughly analyzed: first, the
properties of our multiclass encryption are theoretically investigated by deriving performance bounds on the
recovery quality attained by lower-class receivers with respect to high-class ones. Then, we perform a statistical
analysis of the measurements to show that, although not perfectly secure, compressed sensing grants some level
of security that comes at almost-zero cost and thus may benefit resource-limited applications. In addition to
this, we report some exemplary applications of multiclass encryption by compressed sensing of speech signals,
electrocardiographic tracks and images, in which quality degradation is quantified as the impossibility of some
feature extraction algorithms to obtain sensitive information from suitably degraded signal recoveries.

Signal Recovery from Random Measurements via Extended Orthogonal Matching Pursuit
Sujit Kumar Sahoo, Anamitra Makur
Nanyang Technological University

Abstract
Orthogonal Matching Pursuit (OMP) and Basis Pursuit (BP) are two well-known recovery algorithms in com-
pressed sensing. To recover a $d$-dimensional $m$-sparse signal with high probability, OMP needs $O(m \ln d)$ number
of measurements, whereas BP needs only $O\left(m \ln \frac{d}{m}\right)$ number of measurements. In contrary, OMP is a practi-
cally more appealing algorithm due to its superior execution speed. In this piece of work, we have proposed a
scheme that brings the required number of measurements for OMP closer to BP. We have termed this scheme
as OMP$_\alpha$, which runs OMP for $(m + \lceil \alpha m \rceil)$-iterations instead of $m$ -iterations, by choosing a value of $\alpha \in [0, 1]$.
It is shown that OMP$_\alpha$ guarantees a high probability signal recovery with $O\left(m \ln \frac{d}{\lceil \alpha m \rceil + 1}\right)$ number of meas-
urements. Another limitation of OMP unlike BP is that it requires the knowledge of $m$. In order to overcome
this limitation, we have extended the idea of OMP$_\alpha$ to illustrate another recovery scheme called OMP$_\infty$, which
runs OMP until th-signal residue vanishes. It is shown that OMP$_\infty$ can achieve a close to $\ell_0$-norm recovery
without any knowledge of $m$ like BP.
Blind Inpainting Using $\ell_0$ and Total Variation Regularization
Afonso, M.V., Sanches, J.M.R.

Instituto de Sistemas e Robtica

Abstract
In this paper, we address the problem of image reconstruction with missing pixels or corrupted with impulse noise, when the locations of the corrupted pixels are not known. A logarithmic transformation is applied to convert the multiplication between the image and binary mask into an additive problem. The image and mask terms are then estimated iteratively with total variation regularization applied on the image, and $\ell_0$ regularization on the mask term which imposes sparseness on the support set of the missing pixels. The resulting alternating minimization scheme simultaneously estimates the image and mask, in the same iterative process. The logarithmic transformation also allows the method to be extended to the Rayleigh multiplicative and Poisson observation models. The method can also be extended to impulse noise removal by relaxing the regularizer from the $\ell_0$ norm to the $\ell_1$ norm. Experimental results show that the proposed method can deal with a larger fraction of missing pixels than two phase methods, which first estimate the mask and then reconstruct the image.

Adaptive Image Denoising by Targeted Databases
Enming Luo, Stanley H. Chan, Truong Q. Nguyen

UCSD

Abstract
We propose a data-dependent denoising procedure to restore noisy images. Different from existing denoising algorithms which search for patches from either the noisy image or a generic database, the new algorithm finds patches from a database that contains relevant patches. We formulate the denoising problem as an optimal filter design problem and make two contributions. First, we determine the basis function of the denoising filter by solving a group sparsity minimization problem. The optimization formulation generalizes existing denoising algorithms and offers systematic analysis of the performance. Improvement methods are proposed to enhance the patch search process. Second, we determine the spectral coefficients of the denoising filter by considering a localized Bayesian prior. The localized prior leverages the similarity of the targeted database, alleviates the intensive Bayesian computation, and links the new method to the classical linear minimum mean squared error estimation. We demonstrate applications of the proposed method in a variety of scenarios, including text images, multiview images, and face images. Experimental results show the superiority of the new algorithm over existing methods.
**Optics Express**

*Volume 23, Issue 9*

Nothing of interest.

*Volume 23, Issue 8*

Nothing of interest.

*Volume 23, Issue 7*

Nothing of interest.

**Physical Review E**

*Volume 91, Issue 4*

**Principal-component analysis of particle motion**

H. Y. Chen, R. Liegeois, J. R. de Bruyn, and A. Soddu

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We demonstrate the application of principal-component analysis (PCA) to the analysis of particle motion data in the form of a time series of images. PCA has the ability to resolve and isolate spatiotemporal patterns in the data. Using simulated data, we show that this translates into the ability to separate individual frequency components of the particle motion. We also show that PCA can be used to extract the fluid viscosity from images of particles undergoing Brownian motion. PCA thus provides an efficient alternative to more traditional particle-tracking methods for the analysis of microrheological data.

**Monte Carlo framework for noncontinuous interactions between particles and classical fields**

C. Wesp, H. van Hees, A. Meistrenko, and C. Greiner

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Particles and fields are standard components in numerical calculations like transport simulations in nuclear physics and have well-understood dynamics. Still, a common problem is the interaction between particles and fields due to their different formal description. Particle interactions are discrete, pointlike events while field dynamics is described with continuous partial-differential equations of motion. A workaround is the use of effective theories like the Langevin equation with the drawback of energy conservation violation. We present a method, which allows us to model noncontinuous interactions between particles and scalar fields, allowing us to simulate scattering-like interactions which exchange discrete “quanta” of energy and momentum between fields and particles while obeying energy and momentum conservation and allowing control over interaction strengths and times. In this paper we apply this method to different model systems, starting with a simple harmonic oscillator, which is damped by losing discrete energy quanta. The second and third system consists of an oscillator and a one-dimensional field, which are damped via discrete energy loss and are coupled to a stochastic force, leading to equilibrium states which correspond to statistical Langevin-like systems. The last example is a scalar field in (1+3) space-time dimensions, which is coupled to a microcanonical ensemble of particles by incorporating particle production and annihilation processes. Obeying the detailed-balance principle, the system equilibrates to thermal and chemical equilibrium with dynamical fluctuations on the fields, generated dynamically by the discrete interactions.

**International Journal of Systems Science**

*(Pre-print)*

**Robust maximum likelihood estimation for stochastic state space model with observation outliers**

J. AlMutawa

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The objective of this paper is to develop a robust maximum likelihood estimation (MLE) for the stochastic state space model via the expectation maximisation algorithm to cope with observation outliers. Two types of outliers and their influence are studied in this paper: namely, the additive outlier (AO) and innovative outlier (IO). Due to the sensitivity of the MLE to AO and IO, we propose two techniques for robustifying the MLE: the weighted maximum likelihood estimation (WMLE) and the trimmed maximum likelihood estimation (TMLE). The WMLE is easy to implement with weights estimated from the data; however, it is still sensitive to IO and a patch of AO outliers. On the other hand, the TMLE is reduced to a combinatorial optimisation problem and hard to implement but it is efficient to both types of outliers presented here. To overcome the difficulty, we apply the parallel randomised algorithm that has a low computational cost. A Monte Carlo simulation result shows the efficiency of the proposed algorithms.
Mechatronics (Volume 27)
The Internet of Things – The future or the end of mechatronics Pages 57-74

David Bradley, David Russell, Ian Ferguson, John Isaacs, Allan MacLeod, Roger White

Abstract

The advent and increasing implementation of user configured and user oriented systems structured around the use of cloud configured information and the Internet of Things is presenting a new range and class of challenges to the underlying concepts of integration and transfer of functionality around which mechatronics is structured. It is suggested that the ways in which system designers and educators in particular respond to and manage these changes and challenges is going to have a significant impact on the way in which both the Internet of Things and mechatronics develop over time. The paper places the relationship between the Internet of Things and mechatronics into perspective and considers the issues and challenges facing systems designers and implementers in relation to managing the dynamics of the changes required.

Plus One

European Journal of Control (Volume 20, Issue 4)
The design of model predictive control for an AFM and its impact on piezo nonlinearities Pages 188–198

Md. Sohel Rana, Hemanshu R. Pota, Ian R. Petersen

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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 due to the nonlinear behavior of its scanning unit; i.e., the piezoelectric tube scanner (PTS). In order to increase the imaging speed of the AFM, a model predictive control (MPC) scheme is applied in both the $X$ and $Y$-piezo axes of the PTS to reduce its nonlinearity effects and to improve in damping of the resonant mode. The proposed controller provides an AFM with the capability to achieve improved tracking and it results in the reduction of the hysteresis, creep, vibration, and cross-coupling effects in piezoactuators. The experimental results demonstrate the effectiveness of the proposed control scheme.
**Journal Updates:**

*April 2015*

**Automatica**

*Extremum seeking of dynamical systems via gradient descent and stochastic approximation methods*

*Volume 56, June 2015, Pages 44–52 (Brief paper)*

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**Abstract**

This paper examines the use of gradient based methods for extremum seeking control of possibly infinite-dimensional dynamic nonlinear systems with general attractors within a periodic sampled-data framework. First, discrete-time gradient descent method is considered and semi-global practical asymptotic stability with respect to an ultimate bound is shown. Next, under the more complicated setting where the sampled measurements of the plant’s output are corrupted by an additive noise, three basic stochastic approximation methods are analysed; namely finite-difference, random directions, and simultaneous perturbation. Semi-global convergence to an optimum with probability one is established. A tuning parameter within the sampled-data framework is the period of the synchronised sampler and hold device, which is also the waiting time during which the system dynamics settle to within a controllable neighbourhood of the steady-state input–output behaviour.

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**Coordinate-free formation stabilization based on relative position measurements**

*Volume 57, July 2015, Pages 11–20*

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**Abstract**

This paper presents a method to stabilize a group of agents moving in a two-dimensional space to a desired rigid geometric configuration. A common approach is to use information of relative interagent position vectors to carry out this specific control task. However, existing works in this vein either require the agents to express their measurements in a global coordinate reference, or generally fail to provide global stability guarantees. Our contribution is a globally convergent method that uses relative position information expressed in each agent’s local reference frame, and can be implemented in a distributed networked fashion. The proposed control strategy, which is shown to have exponential convergence properties, makes each agent move so as to minimize a cost function that encompasses all the agents in the team and captures the collective control objective. The coordinate-free nature of the method emerges through the introduction of a rotation matrix, computed by each agent, in the cost function. We consider that the agents form a nearest-neighbor communications network, and they obtain the required relative position information via multi-hop propagation, which is inherently affected by time-delays. We support the feasibility of such distributed networked implementation by obtaining global stability guarantees for the formation controller when these time-delays are incorporated in the analysis. The performance of our approach is illustrated with simulations.
**System & Control Letters**

*Estimation of solutions of observable nonlinear systems with disturbances*

*Volume 79, May 2015, Pages 47–58*

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**Abstract**

A family of continuous-time observable nonlinear systems with input and output is considered. A new technique of estimation of the state variables is proposed. It relies on the use of past values of the output, as done to construct some observers which converge in finite time, and on a recent technical result pertaining to the theory of the monotone systems. It applies to systems with additive disturbances and disturbances in the output. The nonlinear terms are not supposed to be globally Lipschitz, but it is requested that they depend only on the input and output variables.

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**IEEE Transactions on Robotics**

*Unified Terrain Mapping Model With Markov Random Fields*

*Volume 31, Issue 2, Pages 290-306*

Tse, R.; Ahmed, N.R.; Campbell, M.,

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**Abstract**

A terrain mapping model is proposed using a generalized Markov random field (MRF) representation. Unlike previous work, the proposed MRF can fully represent uncertainties due to sensor pose and measurement errors, as well as data association errors in a single model. Additionally, neither homoscedasticity nor a predefined shape of the likelihood distribution is assumed. The flexibility of an MRF model allows spatial height correlations to be incorporated. The ability to include spatial correlations not only improves the accuracy through the benefits of Bayesian prior modeling, but also serves as a basis for terrain property characterization. Maximum likelihood solutions of terrain roughness are derived. Benefits of the proposed model are demonstrated experimentally on indoor and outdoor datasets. Results show that the MRF model leads to lower height estimation errors. In addition, the capability of estimating non-Gaussian height distributions allows the information about individual terrain features to be preserved. Finally, the model is able to accurately estimate the roughness of the terrain, which is beneficial for edge detection of obstacles and nontraversable terrain regions.

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**Multirobot Control Using Time-Varying Density Functions**

*Volume 31, Issue 2, Pages 489-493*

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Abstract
An approach is presented for influencing teams of robots by means of time-varying density functions, representing rough references for where the robots should be located. A continuous-time coverage algorithm is proposed and distributed approximations are given whereby the robots only need to access information from adjacent robots. Robotic experiments show that the proposed algorithms work in practice, as well as in theory.

Bayesian Nonparametric Reward Learning From Demonstration

Volume 31, Issue 2, Pages 369-386

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Abstract
Learning from demonstration provides an attractive solution to the problem of teaching autonomous systems how to perform complex tasks. Reward learning from demonstration is a promising method of inferring a rich and transferable representation of the demonstrator’s intents, but current algorithms suffer from intractability and inefficiency in large domains due to the assumption that the demonstrator is maximizing a single reward function throughout the whole task. This paper takes a different perspective by assuming that the reward function behind an unsegmented demonstration is actually composed of several distinct subtasks chained together. Leveraging this assumption, a Bayesian nonparametric reward-learning framework is presented that infers multiple subgoals and reward functions within a single unsegmented demonstration. The new framework is developed for discrete state spaces and also general continuous demonstration domains using Gaussian process reward representations. The algorithm is shown to have both performance and computational advantages over existing inverse reinforcement learning methods. Experimental results are given in both cases, demonstrating the ability to learn challenging maneuvers from demonstration on a quadrotor and a remote-controlled car.