



HAL
open science

Introduction to the Issue on Stochastic Simulation and Optimization in Signal Processing

Stephen Mc Laughlin, Marcelo Alejandro Pereyra, Alfred O. Hero, Jean-Yves Tourneret, Jean-Christophe Pesquet

► **To cite this version:**

Stephen Mc Laughlin, Marcelo Alejandro Pereyra, Alfred O. Hero, Jean-Yves Tourneret, Jean-Christophe Pesquet. Introduction to the Issue on Stochastic Simulation and Optimization in Signal Processing. IEEE Journal of Selected Topics in Signal Processing, 2016, vol. 10 (n° 2), pp. 221-223. 10.1109/JSTSP.2016.2524963 . hal-01490737

HAL Id: hal-01490737

<https://hal.science/hal-01490737>

Submitted on 15 Mar 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Open Archive TOULOUSE Archive Ouverte (OATAO)

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible.

This is an author-deposited version published in : <http://oatao.univ-toulouse.fr/>
Eprints ID : 17099

To link to this article : DOI : 10.1109/JSTSP.2016.2524963
URL : <https://doi.org/10.1109/JSTSP.2016.2524963>

To cite this version : Mc Laughlin, Stephen and Pereyra, Marcelo Alejandro and Hero, Alfred O. and Tourneret, Jean-Yves and Pesquet, Jean-Christophe *Introduction to the Issue on Stochastic Simulation and Optimization in Signal Processing*. (2016) IEEE Journal of Selected Topics in Signal Processing, vol. 10 (n° 2). pp. 221-223. ISSN 1932-4553

Any correspondence concerning this service should be sent to the repository administrator: staff-oatao@listes-diff.inp-toulouse.fr

Introduction to the Issue on Stochastic Simulation and Optimization in Signal Processing

MANY MODERN signal processing (SP) methods rely very strongly on probability and statistics tools to solve problems; for example, they use stochastic models to represent the data observation process and the prior knowledge available and they obtain solutions by performing statistical inference (e.g., using maximum likelihood or Bayesian strategies). Statistical SP methods are, in particular, routinely applied to many and varied tasks and signal modalities, ranging from resolution enhancement of medical images to hyperspectral image unmixing; from user rating prediction to change detection in social networks; and from source separation in music analysis to automatic speech recognition.

However, expectations and demands are constantly rising and such methods are now expected to deal with ever more challenging SP problems that require ever more complex models, and more importantly ever more sophisticated novel methodologies to tackle them. This has driven the development of computation-intensive SP methods based on stochastic simulation and optimisation. This field, at the interface of SP and computational statistics, has been receiving considerable attention by researchers of late because of its capacity to handle complex models and underpin sophisticated (often Bayesian) statistical inference techniques delivering accurate and insightful results. Promising areas of research in the field include the development of adaptive block-co-ordinate stochastic optimisation algorithms and of efficient simulation techniques for high-dimensional inverse problems.

This special issue seeks to report cutting edge research on stochastic simulation and optimisation methodologies, and their application to challenging SP problems that are *not* well addressed by existing methodologies. We were fortunate to receive 60 papers in total and the selection of the 15, which appear in the special issue was difficult and we are indebted to the many reviewers who assisted us, without their efforts, we would not have been able to produce such a high quality issue. In selecting the 14 papers, we had to make some very difficult choices.

In the survey by Pereyra *et al.*, an introduction to stochastic simulation and optimization methods in signal and image processing is presented. The paper addresses a variety of high-dimensional Markov chain Monte Carlo (MCMC) methods as well as deterministic surrogate methods. It discusses a range of optimization methods adopted to solve stochastic problems, as well as stochastic methods for deterministic optimization and areas of overlap between simulation and optimization, in particular optimization-within-MCMC and MCMC-driven optimization.

On optimization, we have several interesting papers. Konečný *et al.* present a scheme to improve to the theoretical complexity and practical performance of semistochastic gradient descent (S2GD). The novelty of the method is the introduction of mini-batching into the computation of stochastic steps. In Donmez *et al.* the problem of online optimization under adversarial perturbations is considered. Through a worst-case adversary framework to model the perturbations, they present a randomized algorithm that is provably robust against such adversarial attacks. Kail *et al.* consider the task of online data reduction and outlier rejection when large amounts of data are to be processed for inference. Rather than performing these tasks separately, they propose a joint approach, i.e., robust censoring having formulated the problem as a nonconvex optimization problem based on the data model for outlier-free data, without requiring any prior model assumptions about the outlier perturbations. Verliet *et al.* present a randomized block sampling canonical polyadic decomposition method that combines increasingly popular ideas from randomization and stochastic optimization to tackle computational problems. Instead of decomposing the full tensor at once, updates are computed from small random block samples. Carlson *et al.* propose a new, largely tuning-free algorithm to address the problem of training deep probabilistic graphical models. They propose a new, largely tuning-free algorithm to address this problem and derive novel majorization bounds based on the Schatten-1 norm.

In the area of MCMC methods, we have several interesting papers. Septier *et al.* consider a sequential Markov chain Monte Carlo (SMCMC) technique. They provide a unifying framework for a class of SMCMC approaches, coupled with novel efficient strategies based on the principle of Langevin diffusion and Hamiltonian dynamics to cope with the increasing number of high dimensional applications. Murphy and Godsill examine the use of blocking strategies for Particle Gibbs sampling schemes for high dimensional latent state space models with interacting components. Feron *et al.* propose an optimization-guided Gibbs sampler for models involving high dimensional conditional Gaussian distributions. The paper provides an illustration focused on unsupervised estimation for super-resolution methods. Lindsten *et al.* present a forward backward-type Rao-Blackwellized particle smoother (RBPS) that is able to exploit the tractable substructure present in these models. Akin to the well known Rao-Blackwellized particle filter, the proposed RBPS marginalizes out a conditionally tractable subset of state variables, effectively making use of SMC only for the “intractable part” of the model. Schreck *et al.* introduce a new MCMC method for Bayesian variable selection in high dimensional settings. The algorithm is a Hastings–Metropolis sampler with a proposal mechanism, which combines a Metropolis

adjusted Langevin (MALA) step to propose local moves associated with a shrinkage-thresholding step allowing the proposal of new models.

To illustrate the power of the methods that underpin this special issue, we have several papers considering a range of applications. Rached *et al.* consider the evaluation of the outage capacity (OC) at the output of equal gain combining (EGC) and maximum ratio combining (MRC) receivers. This problem consists of computing the cumulative distribution function (CDF) for the sum of independent random variables. Finding a closed-form expression for the CDF of the sum distribution is problematic for a wide class of commonly used distributions, methods based on Monte Carlo (MC) simulations are required. Tan *et al.* consider a compressive hyperspectral imaging reconstruction problem where three-dimensional spatio-spectral information about a scene is sensed by a coded aperture snapshot spectral imager (CASSI). They extend their work on an AMP-Wiener algorithm to three-dimensional hyperspectral image reconstruction, and call it “AMP-3D-Wiener.” The matrix that models the CASSI system is highly sparse, and such a matrix is not suitable for normal AMP methods causing convergence difficulties. Chen *et al.* consider the problem of how to develop a system-wide energy and workload management policy for future sustainable data centers. They leverage stochastic optimization tools, using a proposed unified management approach allowing data centers to adaptively respond to intermittent availability of renewables, variability of cooling efficiency, information technology (IT) workload shift, and energy price fluctuations under long-term quality-of-service (QoS) requirements. Mesejo *et al.* consider the problem of how to measure the blood oxygen level-dependent (BOLD) signal in functional MRI (fMRI). This estimation is challenging because there are more than

10 potentially interesting parameters involved in nonlinear equations and whose interactions may result in identifiability issues.

We hope that the SP community will find these papers stimulating, interesting, and useful in advancing our understanding and use of stochastic simulation and optimisation methods in SP.

STEVE MCLAUGHLIN, *Lead Guest Editor*
Engineering and Physical Sciences
Heriot Watt University
Edinburgh EH14 4AS, U.K.

MARCELO PEREYRA, *Guest Editor*
School of Mathematics
University of Bristol
Bristol, BS8 1TW, U.K.

ALFRED O. HERO, *Guest Editor*
Department of Electrical Engineering and Computer
Science
University of Michigan
Ann Arbor, MI 48109-2122 USA

JEAN-YVES TOURNERET, *Guest Editor*
INP-ENSEEIH-IRIT-TeSA
University of Toulouse
31071 Toulouse, France

JEAN-CHRISTOPHE PESQUET, *Guest Editor*
Laboratoire d’Informatique Gaspard Monge
Université Paris-Est
77454 Marne la Vallée, France



Steve McLaughlin (F’11) received the B.Sc. degree in electronics and electrical engineering from the University of Glasgow, Glasgow, U.K., in 1981, and the Ph.D. degree from the University of Edinburgh, Edinburgh, U.K., in 1990. From 1984 to 1986, he worked on the design and development of high-frequency data communication systems. In 1986, he joined the Department of Electronics and Electrical Engineering, University of Edinburgh, as a Research Fellow, where he studied the performance of linear adaptive algorithms in high noise and nonstationary environments. In 1988, he joined the academic staff at Edinburgh, and from 1991 to 2001, he held a Royal Society University Research Fellowship to study nonlinear signal processing techniques. In 2002, he was a personal Chair in Electronic Communication Systems at the University of Edinburgh. In October 2011, he joined Heriot-Watt University, Edinburgh, U.K., as a Professor of Signal Processing and the Head of the School of Engineering and Physical Sciences. He is a Fellow of the Royal Academy of Engineering, the Royal Society of Edinburgh, and the Institute of Engineering and Technology.



Marcelo Pereyra (S'09–M'13) received the M.Eng. degree in electronic engineering from both ITBA, Buenos Aires, Argentina, and INSA Toulouse, Toulouse, France, in June 2009, the M.Sc. degree in electronic engineering and control theory from INSA Toulouse, in September 2009, and the Ph.D. degree in signal processing from the Institut National Polytechnique de Toulouse, University of Toulouse, Toulouse, France, in July 2012. His research interests include statistical image processing, with a particular interest in Bayesian analysis and computation for high-dimensional inverse problems. He currently holds a Marie Curie Intra-European Fellowship for Career Development at the School of Mathematics, University of Bristol, Bristol, U.K. He is also the recipient of a Brunel Postdoctoral Research Fellowship in Statistics, a Postdoctoral Research Fellowship from French Ministry of Defence, a Leopold Escande Ph.D. Thesis Excellent Award from the University of Toulouse (2012), an INFOTEL R&D Excellent Award from the Association of Engineers of INSA Toulouse (2009), and an ITBA R&D Excellence Award (2007).



Alfred O. Hero (S'79–M'84–SM'98–F'98) received the B.S. degree (*summa cum laude*) from Boston University, Boston, MA, USA, in 1980, and the Ph.D. degree from Princeton University, Princeton, NJ, USA, in 1984, both in electrical engineering. He is the R. Jamison and Betty Williams Professor of Engineering and co-director of the Michigan Institute for Data Science (MIDAS) at the University of Michigan, Ann Arbor. His primary appointment is in the Department of Electrical Engineering and Computer Science and he also has appointments, by courtesy, in the Department of Biomedical Engineering and the Department of Statistics. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE). He has served as President of the IEEE Signal Processing Society and as a member of the IEEE Board of Directors. He has received numerous awards for his scientific research and service to the profession including the IEEE Signal Processing Society Technical Achievement Award in 2013 and the 2015 Society Award, which is the highest career award bestowed by the IEEE Signal Processing Society. Alfred Hero's recent research interests are in the data science of high dimensional spatio-temporal data,

statistical signal processing, and machine learning. Of particular interest are applications to networks, including social networks, multi-modal sensing and tracking, database indexing and retrieval, imaging, biomedical signal processing, and biomolecular signal processing.



Jean-Yves Tournieret (SM'08) received the Ingénieur degree in electrical engineering from the Ecole Nationale Supérieure d'Electronique, d'Electrotechnique, d'Informatique, d'Hydraulique et des Télécommunications (ENSEEIH) de Toulouse, Toulouse, France, in 1989, and the Ph.D. degree from the National Polytechnic Institute Toulouse, Toulouse, France, in 1992. He is currently a professor in the university of Toulouse (ENSEEIH) and a member of the IRIT laboratory (UMR 5505 of the CNRS). His research activities are centered around statistical signal and image processing with a particular interest to Bayesian and Markov chain Monte Carlo (MCMC) methods. He has been involved in the organization of several conferences and has been a member of different technical committees including the Signal Processing Theory and Methods (SPTM) committee of the IEEE Signal Processing Society (2001–2007, 2010–present). He has been serving as an associate editor for the IEEE TRANSACTIONS ON SIGNAL PROCESSING (2008–2011, 2015–present) and for the EURASIP journal on Signal Processing (2013–present).



Jean-Christophe Pesquet (S'89–M'91–SM'99–F'12) received the engineering degree from Supélec, Gif-sur-Yvette, France, in 1987, the Ph.D. degree from the Université Paris-Sud (XI), Paris, France, in 1990, and the Habilitation à Diriger des Recherches from the Université Paris-Sud, in 1999. From 1991 to 1999, he was a Maître de Conférences at the Université Paris-Sud, and a Research Scientist with the Laboratoire des Signaux et Systèmes, Centre National de la Recherche Scientifique (CNRS), Gif-sur-Yvette, France. He is currently a Professor (classe exceptionnelle) with the Université de Paris-Est Marne-la-Vallée, Champs-sur-Marne, France, and the Deputy Director of the Laboratoire d'Informatique of the university (UMR-CNRS 8049). His research interests include multiscale analysis, statistical signal processing, inverse problems, and optimization methods with applications to imaging.