Workshop on High-dimensional Stochastic Simulation and Optimisation in Image Processing

University of Bristol, 27-29 August, 2014

Organised by Marcelo Pereyra

Conference programme

“SuSTaIn is Statistics underpinning Science, Technology and Industry, a programme with the ambitious goal of strengthening the discipline of Statistics in the UK, by equipping it to face the challenges of future applications. Thus the focus is on rigorous and innovative new theory and methodology – core statistics for the 21st century – aimed at and stimulated by generic challenges raised by the ‘data revolution’, in areas as diverse as genomics, astronomy, telecommunications and finance.

It is funded principally by a 3.5million Science and Innovation award from EPSRC, and partly by the University of Bristol, and runs from 2006 to 2016.”

Guy Nason, Director.
Programme

Invited and contributed talks last for 50 and 30 minutes, respectively, including questions.

Day 1: Wednesday 27th August 2014

09.00 – 10.35 Registration & Breakfast
10.35 – 10.50 Welcome session
10.50 – 11.40 Jean-Christophe Pesquet (University of Paris-Est)
11.40 – 11.50 Break
11.50 – 12.40 Christophe Andrieu (University of Bristol)
12.40 – 14.00 Lunch and coffee
14.00 – 14.50 Mario Figueiredo (Technical University of Lisbon)
14.50 – 15.00 Break
15.00 – 15.50 Rafael Molina (University of Granada)
15.50 – 16.20 Coffee break
16.20 – 17.10 Jose Bioucas-Dias (Technical University of Lisbon)
17.30 – 19.30 Wine reception & Poster session

Day 2: Thursday 28th August 2014

09.00 – 09.50 Jean-Yves Tourneret (University of Toulouse)
09.50 – 10.00 Break
10.00 – 10.50 Steve McLaughlin (Heriot Watt University)
10.50 – 11.20 Coffee break
11.20 – 12.10 Florence Forbes (INRIA Grenoble Rhône-Alpes)
12.10 – 14.00 Lunch and coffee
12.50 – 13.50 An Historic Tour of Goldney Hall and Gardens
14.00 – 14.30 Yoann Altmann (Heriot Watt University)
14.30 – 15.00 Jean Lafond (Telecom ParisTech)
15.00 – 15.30 Coffee break
15.30 – 16.00 Nicolas Chauffert (CEA/NeuroSpin & INRIA Saclay)
16.00 – 16.30 Susan Doshi (Cardiff University)
16.30 – 17.00 Xianghua Xie (Swansea University)
20.00 – Dinner (Riverstation)

Day 3: Friday 29th August 2014

09.40 – 10.30 Christian Robert (University of Paris-Dauphine)
10.30 – 10.40 Break
10.40 – 11.30 Peter Green (University of Bristol & UT Sydney)
11.30 – 12.50 Lunch and coffee
Special session on “Convex calculus and optimisation inspired Monte Carlo methods”
12.50 – 13.20 François Orieux (CNRS - Institut d’Astrophysique de Paris)
13.20 – 13.50 Saïd Moussaoui (Ecole Centrale de Nantes)
13.50 – 14.00 Break
14.00 – 14.30 Sylvain Lecorff (CNRS - Université Paris-Sud)
14.30 – 15.00 Marcelo Pereyra (University of Bristol)
15.00 – End of workshop & Pub
Titles of talks (in order of appearance)

Jean-Christophe Pesquet: Stochastic block-coordinate fixed point iterations with applications to splitting.

Christophe Andrieu: Stability and stabilisation of controlled Markov chains and their applications in statistics.

Mario Figueiredo: Optimization algorithms for sparse representations: some history and recent developments.

Rafael Molina: Bayesian modelling and inference with applications to image recovery and classification.

Jose Bioucas-Dias: A convex formulation to image segmentation using hidden fields.

Jean-Yves Tourneret: Non-linear unmixing of hyperspectral images: Myth or reality?

Steve McLaughlin: Residual component analysis of hyperspectral images: Application to joint nonlinear unmixing and nonlinearity detection.

Florence Forbes: High-dimensional regression with a partially-latent variable model: Application to hyperspectral image analysis.

Yoann Altmann: Collaborative sparse regression using correlated supports: Application to hyperspectral unmixing.

Jean Lafond: Adaptive one-bit matrix completion.

Philippe Ciuciu: An accelerated proximal gradient algorithm for gradient waveforms design in Magnetic Resonance Imaging.

Susan Doshi: Statistical image analysis in cone-beam computed tomography.

Xianghua Xie: Combinatorial optimisation for coronary arterial image segmentation.

Christian Robert: Approximate Bayesian Computing (ABC) for model choice: from statistical sufficiency to machine learning.

Peter Green: Emission tomography and Bayesian inverse problems.

François Orieux: Sampling high-dimensional Gaussian distributions for large scale inverses problems.

Saïd Moussaoui: A self-tuning multivariate Gaussian sampler in high dimensions.

Sylvain Lecorff: A shrinkage-thresholding Metropolis adjusted Langevin algorithm for Bayesian variable selection.

Marcelo Pereyra: Proximal Markov chain Monte Carlo algorithms.
Titles of posters


Susan Doshi (Cardiff University): Bayesian statistical analysis in advanced Magnetic Resonance Imaging.


Abstracts (in order of appearance)

Jean-Christophe Pesquet, University of Paris-Est

Stochastic block-coordinate fixed point iterations with applications to splitting.

A main ingredient for proving the convergence of many fixed point algorithms is the fundamental concept of (quasi-)Fejér monotonicity. Popular instances of algorithms grounded on this concept are the Douglas-Rachford algorithm and the Forward-Backward one for solving composite convex minimization problems. With the growing interest in large-scale optimization, block-coordinate methods have gained much popularity since they lead to implementations with reduced complexity and memory requirements per iteration. In this talk, we will show how to obtain block-coordinate versions of a wide class of fixed point algorithms by introducing suitable stochastic sweeping rules. This talk is based on joint work work with Patrick Combettes (UPMC - Sorbonne University) and Audrey Repetti (University of Paris-Est).

Christophe Andrieu, University of Bristol

Stability and stabilisation of controlled Markov chains and their applications in statistics.

The initial motivation for the work presented was to understand the behaviour of popular algorithms used for statistical inference, such as Monte Carlo approximations of the EM (expectation maximisation) algorithm or adaptive Markov chain Monte Carlo methods which fall in the category of controlled Markov chain processes. Informally, given a family of Markov transition probabilities indexed by a parameter, such processes correspond, at a given time instant, to updating the state of the process with one of those transition probabilities whose indexing parameter is chosen according to a rule which may depend on the whole past of the process. Such processes can be particularly unstable when the indexing parameter approaches a set of critical values. The aim of the presentation is to provide some insights into the observed stability of some controlled Markov chains of interest and present some stabilisation techniques which are designed to ensure the stability of the process. As we shall see some of the aforementioned algorithms used in statistics possess natural “strong” stability properties, while others may require the use of stabilisation techniques.

Mario Figueiredo, Technical University of Lisbon

Optimization algorithms for sparse representations: some history and recent developments.

Convex optimization plays a central role in signal/image processing, namely in addressing inverse problems using sparsity-based regularization. The optimization problems resulting from these sparsity-based formulations are characterized by being non-smooth and usually of very high dimensionality, which has stimulated much research in special purpose algorithms. This talk will present an historical overview of this area, from the first algorithms proposed in the early 2000’s to the most recent advances, which are orders of magnitude faster than those early methods. In the last part of the talk, some recent non-convex optimization techniques (namely for blind image deconvolution) will also be addressed.

Rafael Molina, University of Granada

Bayesian modelling and inference with applications to image recovery and classification.

A good part of the research and applications related to image recovery and classification deals with inverse problems, that is, moving from known events back to their most probable causes. Although solutions to inverse problems have been originally derived using numerous approaches,
many of them can be developed and formulated in a systematic fashion within the Bayesian framework.

A fundamental principle of the Bayesian philosophy is to regard all parameters and unobservable variables of a given problem as unknown stochastic quantities, assigning probability distributions based on beliefs. The inference goal is to calculate or approximate the distribution of all the unknowns given the observations. Variational Bayesian (VB) inference is a family of deterministic probability distribution approximation procedures that offer distinct advantages over alternative approaches based on stochastic sampling and those providing only point estimates. VB inference is flexible to be applied in different practical problems, yet is broad enough to subsume as its special cases several alternative inference approaches including Maximum A Posteriori (MAP) and the Expectation-Maximization (EM) algorithm. VB inference and Expectation Propagation are both variational methods that minimize functionals based on the Kullback-Leibler (KL) divergence. Connections between VB and marginalization-based Loopy Belief Propagation (LBP) can also be easily established.

In this talk, we provide an overview of Bayesian modeling and inference methods for image recovery and classification problems. Emphasis will be placed on the pros and cons of VB methods, their connections to other inference methods, and the use of local variational bounds. We will finally conclude the talk with the description of some VB applications.

Jose Bioucas-Dias, Technical University of Lisbon

A convex formulation to image segmentation using hidden fields.

Image segmentation is fundamentally a discrete problem. It consists of finding a partition of the image domain such that the pixels in each element of the partition exhibit some kind of similarity. Very often, the partitions are obtained via integer optimization, which is NP-hard, apart from few exceptions. We sidestep the discrete nature of image segmentation by formulating the problem in the Bayesian framework and introducing a hidden set of real-valued random fields determining the probability of a given partition. Armed with this model, the original discrete optimization is converted into a convex program. To infer the hidden fields, we introduce the Segmentation via the Constrained Split Augmented Lagrangian Shrinkage Algorithm (SegSALSA). The effectiveness of the proposed methodology is illustrated with simulated and real images.

Jean-Yves Tourneret, University of Toulouse

Non-linear unmixing of hyperspectral images: Myth or Reality?

This talk will review some mixing models that can be used for the analysis of hyperspectral images. In addition to the classical linear mixing model, a specific attention will be devoted to bilinear, post non-linear and kernel-based models. Bilinear models can be used to quantify the interactions between the different pure components contained in the image and have shown interesting properties to analyze images in the presence of multipath. Post non-linear models have been considered intensively for source separation. They allow the deviations from the linear mixing model to be captured and as a consequence to build efficient non-linearity detectors for hyperspectral imaging. Finally, in absence of knowledge about the nature of the non-linearities affecting hyperspectral images, the theory of reproducing kernel hilbert spaces can be invoked to build interesting non-linear mixing models. Several algorithms can be used to estimate the parameters of these mixing models. This talk will focus on Bayesian estimation algorithms coupled with Markov chain Monte Carlo methods which have been showing promising results for the unmixing of hyperspectral images.
Steve McLaughlin, Heriot Watt University

Residual component analysis of hyperspectral images: Application to joint nonlinear unmixing and nonlinearity detection.

This talk will discuss a nonlinear mixing model for joint hyperspectral image unmixing and nonlinearity detection. The proposed model assumes that the pixel reflectances are linear combinations of known pure spectral components corrupted by an additional nonlinear term, affecting the end members and contaminated by additive Gaussian noise. A Markov random field is considered for nonlinearity detection based on the spatial structure of the nonlinear terms. The observed image is segmented into regions where nonlinear terms, if present, share similar statistical properties. A Bayesian algorithm is proposed to estimate the parameters involved in the model yielding a joint nonlinear unmixing and nonlinearity detection algorithm. The performance of the proposed strategy is first evaluated on synthetic data. Simulations conducted with real data show the accuracy of the proposed unmixing and nonlinearity detection strategy for the analysis of hyperspectral images. The talk will consider the impact the model has on the efficiency and accuracy of the method.

Florence Forbes, INRIA Grenoble Rhône-Alpes

High-dimensional regression with a partially-latent variable model: Application to hyperspectral image analysis.

The analysis of hyperspectral images often involves solving an inverse problem to deduce a number of physical parameter values from the observed spectra. This inverse problem typically involves a high-dimensional regression that cannot generally be solved directly. To address this issue, the use of training approaches have been considered with the advantage that, once a relationship between physical parameters and spectra has been established through training, the learnt relationship can be used for very large datasets and for all new images underpinned by the same physical model. Within this category of methods, we propose an inverse regression method which exchanges the roles of the input variable (high-dimensional spectrum) and the response variable (low-dimensional physical parameter vector). We introduce a mixture of locally-linear probabilistic mapping model that starts with estimating the above inverse regression, and from which we can deduce closed-form solutions for the forward high-dimensional regression problem of interest. Moreover, we introduce a partially-latent paradigm, such that the vector-valued response variable is composed of both observed and latent entries, thus being able to deal with physical parameters that cannot be observed or, more generally, with data contaminated by experimental artefacts that cannot be explained with noise models. The proposed probabilistic formulation could be viewed as a latent-variable augmentation of regression. We devise expectation-maximization (EM) procedures which facilitate the maximum-likelihood search over the model parameters. The proposed framework is illustrated on real data from the Mars ground collected from the imaging spectrometer OMEGA instrument.

Yoann Altmann, Heriot Watt University

Collaborative sparse regression using correlated supports: Application to hyperspectral unmixing.

This work presents a new Bayesian model and MCMC algorithm for spatially-regularised sparse regression and source separation in vectorial images, with application to hyperspectral image unmixing. Our method is based on a new Bayesian model that represents each image (vectorial) pixel as a noisy linear mixture of sources whose activity/inactivity across the image exhibits significant spatial correlations. The joint posterior distribution of the unknown intensities and activity patterns for each source is then estimated from the data using an MCMC algorithm
and used to compute Bayesian estimators. The proposed methodology is finally demonstrated on a series of experiments using synthetic and real hyperspectral images.

Jean Lafond, Telecom ParisTech

*Adaptive one-bit matrix completion.*

In the past few years, a large variety of works have shown the benefits of using matrix completion techniques to improve recommender system (e.g., for movie or music recommendation). Most works have considered cases where the coefficients are continuous scores. Here, we investigate the case where the observations are binary. More precisely, we deal with the problem of matrix completion when the matrix coefficients follow a logistic distribution with a known concave link function. We assume a general sampling scheme for the acquisition process of the coefficients. We study the performance of a nuclear-norm penalized estimator. More precisely we derive bounds for the Kullback-Leibler divergence between the true and estimated distribution. In practice we propose an algorithm based on coordinate gradient descent in order to tackle potentially high dimensional settings.

Nicolas Chauffert, CEA/NeuroSpin & INRIA Saclay

*An accelerated proximal gradient algorithm for gradient waveforms design in Magnetic Resonance Imaging.*

A fast acquisition of k-space is central to speed up Magnetic Resonance Imaging (MRI). The hardware gradient constraints (magnitude, slew rate) must be accounted for collecting the largest number of samples in a minimal amount of time. However, sampling strategies (e.g., Compressed Sensing, parallel imaging) and optimal gradient waveform design have been so far developed separately. The main drawback of existing methods is that they do not take the sample density into account, although it is central in sampling theory. In particular, methods using optimal control tend to agglutinate samples in high curvature areas. In this talk, we develop an iterative accelerated proximal gradient algorithm to project any parameterization of the k-space trajectory onto the set of feasible curves that fulfills the MRI physical constraints (gradient magnitude, slew rate). We show that our method provides an efficient alternative to optimal control-based method in any case, and that it can be a way of reducing acquisition time while maintaining accurate image reconstruction quality for piece-wise linear trajectories. This talk is based on joint work with Philippe Ciuciu (CEA/NeuroSpin & INRIA Saclay) and Pierre Weiss (CNRS - ITAV).

Susan Doshi, Cardiff University

*Statistical image analysis in cone-beam computed tomography.*

Cone-beam computed tomography (CBCT) is used to verify the position of the prostate prior to radiotherapy. Gold markers may be implanted, allowing the prostate to be located more accurately. These cause artefacts in the 3D reconstructions. I will discuss the application of statistical image analysis techniques to CBCT data with two purposes: estimating the marker locations with an assessment of uncertainty, and creating reconstructions with fewer artefacts. I will describe two approaches. Firstly, we model the markers as they appear in the projection images. By combining information from many projections, we accurately estimate the marker locations in 3D space; however, our uncertainty estimates are not accurate. Secondly, we use a model for the markers in 3D space, modelling the tissue separately. In phantom experiments, we obtain accurate estimates of the tissue properties and marker locations along with an assessment of the uncertainty of these estimates. With patient data, reconstruction artefacts affect the
estimates of tissue properties, but we are able to accurately estimate the marker locations with an assessment of uncertainty of the estimates. Using either approach, we are able to generate reconstructions with fewer artefacts.

**Xianghua Xie, Swansea University**

*Combinatorial optimisation for coronary arterial image segmentation.*

Cardiovascular disease is one of the leading causes of the mortality in the western world. Many imaging modalities have been used to diagnose cardiovascular diseases. However, each has different forms of noise and artefacts that make the medical image analysis field important and challenging. This thesis is concerned with developing fully automatic segmentation methods for cross-sectional coronary arterial imaging in particular, intra-vascular ultrasound and optical coherence tomography, by incorporating prior and tracking information without any user intervention, to effectively overcome various image artefacts and occlusions. Combinatorial optimisation methods are proposed to solve the segmentation problem in polynomial time. A node-weighted directed graph is constructed so that the vessel border delineation is considered as computing a minimum closed set. A set of complementary edge and texture features is extracted. Single and double interface segmentation methods are introduced. Novel optimisation of the boundary energy function is proposed based on a supervised classification method. Shape prior model is incorporated into the segmentation framework based on global and local information through the energy function design and graph construction. A combination of cross-sectional segmentation and longitudinal tracking is proposed using the Kalman filter and the hidden Markov model. The border is parameterised using the radial basis functions. The Kalman filter is used to adapt the inter-frame constraints between every two consecutive frames to obtain coherent temporal segmentation. An HMM-based border tracking method is also proposed in which the emission probability is derived from both the classification-based cost function and the shape prior model. The optimal sequence of the hidden states is computed using the Viterbi algorithm. Both qualitative and quantitative results on thousands of images show superior performance of the proposed methods compared to a number of state-of-the-art segmentation methods.

**Christian Robert, University of Paris-Dauphine**

*Approximate Bayesian Computing (ABC) for model choice: from statistical sufficiency to machine learning.*

Since its introduction in the late 1990’s, the performances of the ABC method have been analysed from several perspectives, starting with the pure practical motivations of the population geneticists who created it to an approximate Bayesian method, to a non-parametric one. We cover in this talk a new vision the specific case of model selection, showing how we originally developed convergent methods for Gibbs random fields, before moving to a pessimistic view of the consistency of the method and producing necessary and sufficient conditions for this consistency to hold, then to the realisation that generic machine learning tools like KNNs and random forests should be put to use to run model selection in the complex models covered by ABC techniques. Our perspective radically alters the way model selection is operated as we ban approximations of posterior probabilities for the models under comparison, since they cannot be reliably estimated, and propose instead to compute the performances of the selection method. As an aside, we argue that both KNN and random forest methods can be adapted to the settings of interest, with a recommendation on the automated selection on the tolerance level and sparse implementations of the random forest tree construction, using subsampling and reduced reference tables. This talk is based on joint works with Jean-Marie Cornuet, Arnaud Estoup (INRA - CBGP), Jean-Michel Marin (University of Montpellier II), Natesh
Pillai (Harvard University), Pierre Pudlo (University of Montpellier II & INRA - CBGP) and Judith Rousseau (University of Paris-Dauphine).

Peter J Green, University of Bristol & UT Sydney
Emission tomography and Bayesian inverse problems.
Inverse problems are almost ubiquitous in applied science and technology, so have long been a focus for intensive study, aimed at both methodological development and theoretical analysis. Formulating inverse problems as questions of Bayesian inference has great appeal in terms of coherence, interpretability and integration of uncertainty: the Bayesian formulation comes close to the way that many scientists intuitively regard the inferential task, and in principle allows the free use of subject knowledge in probabilistic model building.

The Bayesian approach to reconstruction in single-photon emission computed tomography will be briefly discussed, with several empirical illustrations. Theoretical results about consistency of the posterior distribution of the reconstruction will then be presented, along with a version of the Bernstein–von Mises theorem that provides an effective approximation to the posterior distribution in such ill-posed partly-non-regular generalised linear inverse problems with constraints. This talk is based on joint work with Natalia Bochkina (University of Edinburgh).

François Orieux, CNRS - Institut d’Astrophysique de Paris
Sampling high-dimensional Gaussian distributions for large scale inverse problems
Current inverse problems often involve high-dimensional data sets that require fully automatic analysis methods. Bayesian models and algorithms can be very useful in this context, particularly Gaussian and conditional Gaussian models coupled with Markov chain Monte Carlo sampling algorithms. Unfortunately, many important problems lead to high-dimensional Gaussian posterior densities that are difficult to sample with traditional sampling algorithms. This presentation will describe an efficient sampling algorithm to draw high-dimensional Gaussian vectors based on an optimisation procedure preceded by a perturbation. The proposed algorithm is valid in the general case of linear (non-convolutive) data observation models and finds direct applications in myopic/unsupervised inversion methods as well as in some non-Gaussian inversion methods. We will conclude with several illustrations related to astronomy and microscopy.

Saïd Moussaoui, Ecole Centrale de Nantes
A self-tuning multivariate Gaussian sampler in high dimensions.
Drawing samples from a multivariate Gaussian distribution in high dimensions is a major step in many statistical inference problems, such as those encountered in machine learning, image processing and inverse problems. Here, we consider that the Gaussian distribution is defined by its precision matrix (inverse of the covariance) and the product of this precision matrix with the Gaussian mean. Such a situation is commonly encountered in the context of Bayesian inference, where the sampled Gaussian is one of the components of the full posterior distribution. Direct sampling of a multivariate Gaussian distribution is traditionally performed using a Cholesky factorization of the covariance matrix. An alternative method is based on the resolution of a linear system involving the precision matrix, its Cholesky factor or square root. However, due to their numerical complexity and memory requirement, both approaches are infeasible in high dimensions, unless the precision matrix presents some specific structure. In this talk, we will firstly recall some existing approaches allowing to avoid the Cholesky factorization and the exact resolution of a linear system. Then, we will introduce a method called RJPO (reversible jump perturbation optimization). RJPO incorporates an approximate resolution of a linear system
with an accept-reject step ensuring the convergence towards the target distribution. We will also propose an unsupervised adaptive scaling of the RJPO sampler to optimize the numerical efficiency in terms of minimal computation cost per effective sample. This talk is based on joint work with Jérôme Idier (Ecole Centrale de Nantes) and Clément Gilavert (Ecole Centrale de Nantes).

Sylvain Lecorff, CNRS - Université Paris-Sud
*A shrinkage-thresholding Metropolis adjusted Langevin algorithm for Bayesian variable selection.*

This talk introduces a new Markov Chain Monte Carlo method to perform Bayesian variable selection in high dimensional settings. Variable selection is a complicated task when the number of regression parameters is much larger than the number of observations. In this context, it is crucial to introduce sparsity assumptions based on the prior knowledge that only a few number of regression parameters are significant. The algorithm aims to determine which components of the regression vector are significant and to estimate the regression vector. The algorithm is a Hastings-Metropolis sampler with a proposal mechanism which combines (i) a Metropolis adjusted Langevin step to propose local moves associated with the differentiable part of the target density with (ii) a shrinkage-thresholding step based on the non-differentiable part of the target density. This second step provides sparse solutions since small components are shrunk toward zero. This algorithm can perform global moves from one model to a distant other one, which allows to explore efficiently high dimensional state-spaces. The talk presents also the geometric ergodicity of this new transdimensional Markov Chain Monte Carlo sampler is established.

Marcelo Pereyra, University of Bristol
*Proximal Markov chain Monte Carlo algorithms.*

Convex optimisation and stochastic sampling are two powerful computational methodologies for performing statistical inference in high-dimensional inverse problems. It is widely acknowledged that these methodologies can complement each other very well, yet they are generally studied and used separately. This talk presents two new Langevin Markov chain Monte Carlo methods that use elements of convex analysis and proximal optimisation to simulate efficiently from high-dimensional densities that are log-concave. The methods are based on a new first-order approximation for Langevin diffusions that uses Moreau-Yoshida approximations and proximity mappings to capture the log-concavity of the target density and construct Markov chains with favourable convergence properties. The methods are shown to be geometrically ergodic in many cases where the conventional Langevin MCMC algorithms are transient or explosive and do not converge geometrically. The proposed methodology is demonstrated on a series of illustrative examples and on two challenging high-dimensional applications related to audio compressive sensing and image resolution enhancement.
Abstracts (posters)

Philippe Ciuciu, CEA/NeuroSpin & INRIA Saclay

*Physiologically informed Bayesian analysis of ASL functional Magnetic Resonance Imaging data using Markov chain Monte Carlo.*

ASL fMRI data provides a quantitative measurement of blood perfusion. In contrast to Blood Oxygenation Level-Dependent signal, the ASL signal is a direct and closer to neuronal activity measurement. However, ASL data has a lower signal-to-noise ratio (SNR) and poorer resolution, both in time and space. In this work, we thus aim to take advantage of the physiological link between the hemodynamic (venous) and perfusion (arterial) components in the ASL signal to improve the estimation of the impulse responses of the neurovascular system. In a Bayesian framework, a linearization of this link is injected as prior information to temporally regularize the regionwise estimation of the perfusion response function while enabling the joint detection of brain activity elicited by stimuli delivered along a fast event-related paradigm. All the parameters of interest in space and time as well as hyper-parameter are computed in the posterior mean sense after convergence of a hybrid Metropolis-Gibbs sampler. In this way, we aim at providing clinically relevant perfusion characteristics for the analysis of ASL data in low SNR conditions. This talk is based on joint work with Aina Frau (INRIA Grenoble Rhône-Alpes), Thomas Vincent (INRIA Grenoble Rhône-Alpes) and Florence Forbes (INRIA Grenoble Rhône-Alpes).

Susan Doshi, Cardiff University

*Bayesian statistical analysis in advanced Magnetic Resonance Imaging.*

Magnetic resonance phenomena may be used to probe tissue microstructure, particularly in the white matter of the brain. The measured signal is affected by the diffusion of water according to the magnetic gradient field applied, allowing the anisotropic nature of this diffusion to be characterised. The anisotropy is interpreted as being due to greater diffusion parallel to the nerve fibres. There are several different physical models which may be used, including anisotropic Gaussian diffusion (described by a diffusion tensor) and those including diffusion restricted to cylinders (such as the CHARMED model [1], which includes both Gaussian and restricted diffusion). In this work, we have used a Bayesian statistical approach to estimate the parameters of the CHARMED model. The prior probability of the parameters is a Markov random field (MRF); the likelihood is Gaussian. We have chosen this approach as it is flexible, allowing the integration of other measurements of tissue microstructure. For example, relaxometry methods (such as mcDESPOT [2]) provide estimates of the myelin water fraction. Our prior expectation is of smoothness within white matter tracts, whose orientation may be probed using measurements of diffusion. We have achieved effective regularisation of the parameters. We shall present results using different forms for the potential function defining the MRF.


Mohammed El Hassouni, University of Mohammed V-Agdal

Statistical modeling of natural images: Application to texture classification and quality assessment.

Nowadays, image interpretation is at the heart of many industrial processes sectors. From aeronautics to geophysics through the medical sector, all sectors use the image compression, classification, indexing, segmentation and/or denoising applications. While most technological obstacles regarding the acquisition and visualization of the image are now removed, some remain and prevent the development of reliable and sustainable applications. This work lies at the crossroads between statistics and image processing and 3D meshes. Stochastic modeling and calculation of similarity metrics are the foundation of my theoretical work to develop novel approaches that solve classical problems in image processing. In this talk, I will present some obtained results by the application of statistical modeling in color textures characterization, natural images quality assessment. We use a multivariate statistical models to characterize dependencies that exists between color channels, inter and intra wavelets subbands. Then, use propose some closed-forms of similarity measurement between theses models. Finally, we give some results on the best known databases.

Yosra Marnissi, University of Paris-Est

A majorize-minimize adapted Metropolis-Hastings algorithm.

One challenging task in MCMC methods is the choice of the proposal density in the Metropolis-Hastings algorithm. It should ideally provide an accurate local approximation of the target density with a low computational cost. In particular, we are interested in MCMC methods based on the discretization of the Langevin diffusion. In order to accelerate the convergence, these methods construct proposals that account for a directional component pushing the chain towards areas of high probability where most samples lie. We propose a novel method for tuning the related directional component. The latter one is preconditioned by an adaptive matrix based on a Majorize-Minimize strategy. This new procedure is shown to exhibit a good performance compared with the standard MALA algorithm.

Konstantinos Themelis, National Observatory of Athens

A variational Bayes scheme for semi-supervised hyperspectral image unmixing.

Our research focuses on the development of efficient variational Bayes methods for (un/semi) supervised hyperspectral image unmixing. Hyperspectral data are big, high dimensional data that exhibit strong correlations. Therefore, spectral unmixing calls for sophisticated signal processing methods of low computational complexity. In the field of Bayesian analysis for hyperspectral unmixing, many methods have been proposed that employ MCMC sampling to perform posterior inference. Although MCMC methods converge to the true posterior after drawing a large number of samples, they are not well-suited for unmixing large images, due to their vast computational complexity. To alleviate this, we have recently proposed in [1] a fast, deterministic variant of the Gibbs sampler, which is shown to be a first-order approximation to a variational Bayes scheme. Note that variational Bayes methods do not guarantee the recovery of the true posterior, however, they are able to approximate it and they converge much faster than MCMC methods. In our poster we wish to present a modified version of the work in [1] for the ill-posed inverse problem of abundance estimation. Abundances are termed the proportional percentages of the materials’ spectral signatures in each pixel of a hyperspectral scene. In our semi supervised setting, each pixel’s abundance vector is assumed to be (a) nonegative and (b) sparse, in the sense that only a few material will be present in each pixel, e.g., [1]. In our proposed Bayesian
model, we assume that the abundances follow a nonnegatively truncated Gaussian distribution with exponential distributed variances. Specifically, we deploy the generalized inverse Gaussian distribution over the precisions of the abundances, so as to derive a generalized, nonnegative, heavy-tailed prior over the abundance coefficients. Special cases of our generalized prior are the Student-t or the multivariate Laplace distribution, that are widely used in Bayesian compressive sensing. Following the mean field approximation theory, we propose a per-coordinate factorization of the approximating posterior distribution (the reason being that we are contrived to work with the close forms for the mean and the variance of the one dimensional truncated Gaussian distribution). The proposed factorization gives rise to an iterative scheme, where the variational parameters of our approximating posterior are updated in a cyclic manner. Experimental results are provided in both simulated and real hyperspectral data, that demonstrate the estimation performance of the proposed method.