Master's Internship

« Sequential Monte Carlo Methods in High-Dimensional Spaces »

Supervisors: F. Septier (Telecom Lille / LAGIS) and E. Duflos (Ecole Centrale Lille / LAGIS)
Location: Lille – Research visits in London envisaged
Collaboration: Department of Statistical Science, University College of London (UK)
Duration: 5/6 months – starting as soon as possible
Keywords: Bayesian Inference, Sequential Monte-Carlo, High-dimensionnal problems.

In many signal processing applications, it is required to estimate a latent or ``hidden'' process (the ``state'' of the system) from noisy, convolved or non-linearly distorted observations. Since data also arrive sequentially in many applications it is therefore desirable (or essential) to estimate the hidden process on-line, in order to avoid memory storage of huge datasets and to make inferences and decisions in real time. Some typical applications from the engineering perspective include: Tracking for radar and sonar applications, Real-time enhancement of speech and audio signals, Sequence and channel estimation in digital communications channels, Medical monitoring of patient EEG/ECG signals, Image sequence tracking, ... In this context, the data are typically modeled by state-space models (also referred as Hidden Markov Model) with linear or nonlinear functions and noise sources that are assumed either Gaussian or non-Gaussian. When the models describing the data are linear and the noise is Gaussian, the optimal solution is the renowned Kalman filter. For models that deviate from linearity and Gaussianity, various approximation methods have been developed among which the extended Kalman filter is perhaps the best known.

Few years ago Gordon et al. published an article on nonlinear and non-Gaussian state estimation which introduced a new method, called Particle Filter (PF) or Sequential Monte Carlo method (SMC), for sequential signal processing based on Monte Carlo sampling. It has been showed that this method has profound potential. Using these sequential Monte Carlo methods, the obtained estimates of the hidden state can be set arbitrarily close to the optimal solution (in the Bayesian sense) at the expense of computational complexity. Not surprisingly, it has incited a great deal of research, which has contributed to making sequential signal processing by Monte Carlo methods one of the most prominent developments in statistical signal processing in the recent years with application to finance, insurance risk, multi-target tracking, computer vision, navigation and localization, digital communication, ...

However, due to their sampling mechanization, SMC methods tend to be inefficient when applied to high-dimensional problems. For a reasonable number of particles (i.e. for a given computation power), performance of such methods is currently far from optimal since with stochastic algorithms, it is currently difficult to design a satisfactory exploration of a high-dimensional state space. In this internship, we will firstly study the theoretical limitations of such approaches that will help us to design new space exploration strategies. Then, we will compare recent advanced Monte-Carlo methodologies and propose new solutions to address complex and challenging sequential inference problems.

Interested applicants are invited to send their curriculum vitae to both François Septier (francois.septier@telecom-lille1.eu) and Emmanuel Duflos (emmanuel.duflos@ec-lille.fr).