Guest Editorial
Special Issue on Monte Carlo Methods for Statistical Signal Processing

THE importance of Monte Carlo methods for inference in science and engineering problems has grown steadily over the past decade. This growth has largely been propelled by an explosive increase in accessible computing power. In association with this growth in computing, it has become clear that Monte Carlo methods can significantly expand the class of problems that can be addressed practically. One area that has seen the benefits of these developments and has shown noteworthy advances is statistical signal processing.

Monte Carlo methods originated in theoretical physics, where they were used for simulation of highly complex systems. Later, their use spread to other disciplines. Compared with more traditional techniques, Monte Carlo methods have much greater flexibility for the solution of challenging computational problems, including optimization and integration. Such problems abound in statistical signal processing, and therefore, it is not surprising that Monte Carlo methods are rapidly becoming a regular tool for tackling them. A common feature of these methods is the drawing of random samples from relevant probability distributions and the subsequent use of these samples for the computation of various estimates, for decision making, and for inference problems in general. Monte Carlo methods have, in recent years, been most commonly associated with inference in the Bayesian paradigm, and this emphasis is refelcted in the contents of this Special Issue. For example, the use of Markov chain Monte Carlo sampling for high-dimensional parameter estimation or the reversible jump Markov chain Monte Carlo sampling for model selection (detection) are rapidly finding acceptance in the signal processing community. Similarly, in adaptive signal processing, the exploitation of Monte Carlo particle filtering for tracking of dynamic signals and sequential estimation of their parameters is proliferating in applications. More recently, other methods, such as perfect sampling, are gaining in popularity and interest. Finally, Monte Carlo methods such as the bootstrap and importance sampling, which have been standard techniques for quite some time in a statistician's repertoire, are still finding novel applications in signal processing.

The objective of this Special Issue is to present the latest research results in Monte Carlo methods for statistical signal processing and to bring their enourmous scope even closer to the signal processing community. This issue is composed of papers that emphasize different aspects of the methods.[1] A few papers are tutorial in nature, whereas others are focused on new theory and/or specific applications in signal processing. There are three tutorial papers: One is on particle filters for online tracking of unknowns; another surveys convergence results on particle filtering; a third reviews the concept of perfect sampling and provides examples that show its application to signal processing. The remaining papers address various topics, including theory and practice of Markov chain Monte Carlo sampling, importance sampling, sequential importance sampling, perfect sampling, and the bootstrap method. Applications include wavelet reconstruction of signals, processing of frequency-modulated signals, video sequence restoration, image restoration for interferometric synthetic aperture radar, tracking of multiple moving targets, positioning and navigation of moving platforms, adaptive detection and decoding in flat-fading communication channels, blind symbol detection in wireless orthogonal frequency-division multiplexing systems, tracking of nonstationary network behavior, audio signal enhancement, curve fitting, and joint detection and estimation of sources in colored noise.

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[1]Due to the size of this issue, three papers of the Special Issue will be published in the March edition of the TRANSACTIONS. They include "A Survey of Convergence Results on Particle Filtering Methods for Practitioners," by D. Crisan and A. Doucet; "Bayesian Analysis of Generalized Frequency Modulated Signals," by K. Copsey, N. Gordon, and A. Marrs; and "Bayesian Curve Fitting Using MCMC with Applications to Signal Segmentation," by E. Punskaya, C. Andrieu, A. Doucet, and W. Fitzgerald.