

Workshop Proposal for the 2006 American Control Conference

STOCHASTIC SEARCH AND OPTIMIZATION

Workshop Instructors and Organizers: James C. Spall and Stacy D. Hill, both of the Johns Hopkins University, Applied Physics Laboratory (further information below).

Contact:

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Workshop Length: One day (approximately 7 hours of class time).

Intended Audience: General participants at the ACC (academic and non-academic). The course will be balanced between theory and practice and, hence, could potentially have broad appeal.

Goal: This workshop will review stochastic search and optimization algorithms and analysis techniques that are widely used in the control systems community. The emphasis will be on general principles and comparative analysis. Participants will learn:

- Fundamental principles underlying stochastic search and optimization techniques,
- Widely used optimization methods and to recognize when such methods are necessary or beneficial,
- Advantages and disadvantages of popular methods for stochastic optimization.

Summary:

This workshop is an introduction to stochastic search and optimization, as oriented to systems and control problems and applications. Stochastic search and optimization play an important role in the analysis and control of modern systems as a way of coping with inherent system noise and providing algorithms that are relatively insensitive to modeling uncertainty. Methods for stochastic search and optimization are used throughout virtually all aspects of control theory and practice, a few of which are: decision aiding, system identification, aircraft flight control, simulation-based optimization of discrete-event systems, performance analysis of communication networks, control and scheduling of complex manufacturing processes, and computer-based personnel training.

This workshop introduces fundamental issues in stochastic search and optimization with special emphasis on cases where classical deterministic techniques (e.g., linear and nonlinear

programming) do not apply. These cases include many important practical problems, which will be mentioned throughout the course (e.g. target tracking, nonlinear control, image processing, queueing network control, neural network training, discrete-event systems). Global and local optimization algorithms for discrete and continuous problems will be discussed. These algorithms include random search, recursive least squares and least mean squares, stochastic approximation, simulated annealing, and genetic algorithms. We will discuss the relationships among these methods and provide some guidance about which methods are appropriate for which problems.

The objectives of this workshop are to introduce concepts and statistical techniques that are critical to stochastic search and optimization and to address issues relevant to both researchers and industrial practitioners. The course will not delve into detailed theoretical aspects related to the methods, but will direct participants to the specific literature for such material. The total workshop time will be approximately seven hours and will focus on basic issues in algorithm design, core theoretical foundations, and practical implementation. Some specific applications will be briefly discussed to illustrate practical implementation issues, but because of the general appeal of the algorithms and because of time restrictions, the workshop will not dwell on the details of any specific application.

The topics to be covered are listed below in the approximate order of presentation:

Major Topics:

I. Background (S. D. Hill)

Basic issues in search and optimization; stochastic vs. deterministic methods; summary of classical methods of optimization and their limitations. Brief review of necessary multivariate analysis, matrix algebra, probability, and statistics.

II. Direct Search (S. D. Hill)

Introduction to direct random search; Monte Carlo methods; nonlinear simplex (Nelder-Mead) algorithm

III. Stochastic Approximation for Linear and Nonlinear Systems (J. C. Spall and S. D. Hill)

Recursive methods for linear systems: recursive least squares and least mean squares.
Root-finding and gradient-based stochastic approximation (Robbins-Monro).
Gradient-free stochastic approximation: finite-difference and simultaneous perturbation methods.

IV. Methods Motivated by Physical Processes for Global Optimization (J. C. Spall)

Simulated annealing and related methods. Evolutionary computation with an emphasis on genetic algorithms.

V. Wrap-up and Discussion (J. C. Spall and S. D. Hill)

Prerequisites: Knowledge that should be part of the background typical of ACC attendees: graduate course in probability and statistics; familiarity with basic matrix analysis and linear

algebra. Some MATLAB-based exercises will be discussed for participants to carry out after the workshop.

Handout/Textbook: A complete set of PowerPoint slides and a list references will be given to all participants. The optional workshop textbook will be *Introduction to Stochastic Search and Optimization*, J. C. Spall, Wiley, New York, 2003.

Background of Instructors:

The course will be taught on approximately a 50–50 basis by the following two instructors:

James C. Spall is a member of the Principal Professional Staff at the Johns Hopkins University, Applied Physics Laboratory, and is a Research Professor in the Johns Hopkins Department of Applied Mathematics and Statistics (Homewood campus). He is also Chairman of the Applied and Computational Mathematics Program within the Johns Hopkins University Engineering Programs for Professionals. Dr. Spall has published many articles in the areas of statistics and controls and holds two U.S. patents in the area of adaptive control.

Previous Workshops and Tutorials:

The proposed workshop is an updated version of a workshop that Drs. Spall and Hill gave at the 2003 ACC, which attracted 10 (ten) participants. A related workshop on simulation and Monte Carlo methods was offered at the 2001 Conference on Decision and Control and the 2004 ACC and attracted, respectively, 12 and 14 participants.

Drs. Spall and Hill co-taught a three-day short course on stochastic methods in optimization and simulation at the NASA John H. Glenn Research Center (August 2005). Dr. Spall has given workshops and tutorials on stochastic search and optimization at a number of technical conferences, including the Summer Computer Simulation Conference, the Annual Meetings of the American Statistical Association, the Military Operations Research Society Annual Meeting, the International Joint Conference on Neural Networks, and the International Conference on Information Fusion. The participants at these conference workshops and tutorials were a blend of practicing engineers and scientists, academics, and graduate students.