

## **Proposed Workshop for 2007 ACC**

### **SIMULATION AND MONTE CARLO METHODS**

**Instructors:** James C. Spall and I-Jeng Wang, both of the Johns Hopkins University, Applied Physics Laboratory (further information below).

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**Duration of workshop:** One day

#### **Summary**

This workshop is an introduction to simulation and Monte Carlo methods as oriented to systems and control problems. Simulation and related Monte Carlo methods provide a powerful tool for the analysis of real-world systems when the system is not amenable to traditional analytical approaches. Areas where simulation-based approaches have emerged as indispensable include decision aiding, prototype development for large-scale control systems, performance analysis of communication networks, control and scheduling of complex manufacturing processes, and computer-based personnel training. The objective of this workshop is to introduce concepts and statistical techniques that are critical to constructing and analyzing effective simulations, and to discuss certain applications for simulation and Monte Carlo methods with a focus on problems of interest to the control systems community. The workshop addresses issues relevant to both researchers and industrial practitioners.

#### **Description**

Computer simulation and related Monte Carlo methods are widely used in engineering and scientific work. Simulation provides a powerful tool for the analysis of real-world systems when the system is not amenable to traditional analytical approaches. In fact, recent advances in hardware, software, and user interfaces have made simulation a "first line" method of attack for a growing number of problems. Areas where simulation-based approaches have emerged as indispensable include decision aiding, prototype development for large-scale control systems, performance analysis of communication networks, control and scheduling of complex manufacturing processes, and computer-based personnel training. Large stochastic simulations arising in these and other areas present great challenges in the design of the simulation models

and in the analysis of output data. The objective of this workshop is to introduce concepts and statistical techniques that are critical to constructing and analyzing effective simulations, and to discuss certain applications for simulation and Monte Carlo methods with a focus on problems of interest to the control systems community.

This workshop addresses important issues relevant to the design, application, and interpretation of simulation and Monte Carlo methods. Listed below is a tentative schedule of the course topics and associated time allocation. We will assign the relevant instructor (JCS or IJW) at a later time.

8:30–9:00 Course overview and very brief review of relevant probability and statistical methods  
 9:00–9:30 Computer-based (pseudo) random number generation  
 9:30–10:15 Stochastic timed discrete-event systems model and discrete-event simulations  
 10:15–10:30 Break  
 10:30–11:15 Issues in model building (bias-variance tradeoff, model selection, etc.)  
 11:15–12:00 Simulation-based optimization (use of simulations for optimizing system performance) with non-gradient methods (finite-difference, SPSA, etc.); common random numbers in optimization  
 12:00–1:15 Lunch  
 1:15–2:15 Simulation-based optimization (cont'd), including gradient-based methods such as IPA, LR, etc.  
 2:15–3:00 Input selection and optimal experimental design  
 3:00–3:15 Break  
 3:15–4:00 Variance reduction techniques for simulation output  
 4:00–4:45 Markov chain Monte Carlo (MCMC) methods  
 4:45–5:00 Wrap-up and open discussion.

### **Prerequisites**

Knowledge that should be part of the background of almost all ACC attendees: Undergraduate courses in probability and statistics and multivariate calculus; familiarity with basic matrix analysis and linear algebra. Some practical experience with statistical analysis and simulation will be helpful. Some MATLAB-based exercises will be discussed for participants to carry out after the workshop.

### **Textbooks/References**

A complete set of PowerPoint slides and a comprehensive list of references will be given to all participants. Several of the key references are:

- Cassandras, C. G. and Lafortune, S. (1999), *Introduction to Discrete Event Systems*, Kluwer, Boston.  
 Law, A. M. (2006), *Simulation Modeling and Analysis*, 4<sup>th</sup> ed, McGraw-Hill, New York.  
 Rubinstein, R. Y. and Melamed, B. (1998), *Modern Simulation and Modeling*, Wiley, New York.

Spall, J. C. (2003), *Introduction to Stochastic Search and Optimization: Estimation, Simulation, and Control*, Wiley, Hoboken, NJ.

### Background on Instructors

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

**James C. Spall** ([www.ams.jhu.edu/ams/people/faculty.html](http://www.ams.jhu.edu/ams/people/faculty.html)) 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 (EPP). Dr. Spall has published many articles in the areas of statistics and control and holds two U.S. patents for inventions in control systems. He was the editor and coauthor for the book *Bayesian Analysis of Time Series and Dynamic Models* (Marcel Dekker, 1988) and is the author of *Introduction to Stochastic Search and Optimization* (Wiley, 2003). He won the EPP Excellence in Teaching Award in 2006 (one of 3 awards from approximately 400 faculty). Among other appointments, he is an Associate Editor at Large for the *IEEE Transactions on Automatic Control* and a Contributing Editor for the *Current Index to Statistics*. Dr. Spall has served on several Program Committees for the IEEE Conference on Decision and Control (CDC) and the American Control Conference (ACC), served as the Vice Chair for invited sessions at the 2001 CDC, Vice Chair for contributed papers at the 2002 ACC, Vice Chair for short papers at the 2004 CDC, and Area Editor for stochastic systems and related topics at the 2005 CDC. He is the Program Chair for the 2007 CDC. Dr. Spall has received numerous research and publications awards and is a Fellow of IEEE.

**I-Jeng Wang** joined the Research and Technology Development Center at JHU/APL in 1997, following postdoctoral and research positions at Purdue University and the University of Maryland. He is a member of the Principal Professional Staff at JHU/APL and an Assistant Research Professor in the Johns Hopkins Department of Computer Science (Homewood campus). Dr. Wang has published in the signal processing and control literature, and is active in research on network control and management, probabilistic inference, and simulation analysis. Dr. Wang has led a government-sponsored R&D effort (involving multiple research institutions) to develop efficient networking techniques for managing large-scale distributed communication networks. He has participated in and contributed to several information technology and control projects where stochastic simulation and related approaches play integral roles. His current research is focused on distributed information processing and sensor management in wireless sensor networks. He is a member of IEEE. He served on the Program Committee for the 2001, 2004, and 2005 CDC and more recently for the 2006 ACC.

### Related Previous Workshops and Courses; Instructor Experience

An earlier version of this workshop was given at the 2004 ACC (Boston, MA); there were 14 registrants at that workshop. Drs. Spall and Wang have also given extended (multiple week)

versions of this course as part of a non-credit series of courses for working professionals at JHU/APL and as part of the graduate school of the JHU School of Engineering (credit). The proposed offering for ACC 2007 will be updated and modified to reflect the experience acquired in teaching the previous workshop, non-credit, and credit offerings.

Dr. Spall has taught many tutorials and workshops at professional conferences. Aside from the above-mentioned course on simulation at the 2004 ACC, Dr. Spall has taught or co-taught workshops on stochastic methods and optimization at the Summer Computer Simulation Conference (1997), the American Statistical Association Annual Meeting (1996, 1999, and 2001), the U. S. Army Artificial Intelligence Symposium (1996), the Military Operations Research Society Annual Meeting (1997 and 2001), the International Joint Conference on Neural Networks (1999), International Conference on Fusion (2005), the CDC (2001), and the ACC (2003 and 2006). The participants at these workshops and tutorials were a blend of practicing engineers and scientists, academics, and graduate students.

Dr. Wang has taught a course on system modeling and analysis at the Institute for Systems Research, University of Maryland. He co-teaches a graduate course on sensor networks at the JHU Computer Science Department. Aside from the above-mentioned 2004 ACC course, Dr. Wang co-taught (with J. C. Spall) a workshop on Monte Carlo and simulation at the 2001 American Statistical Association Annual Meeting and at the 2001 CDC.