ESI 6529: Digital Simulation Techniques
Fall 2007
Section Number: 2635X

Class hours: M, W, F 2nd period

Classroom: Weil 234

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Course Objectives:
The purpose of the course is to introduce fundamental concepts and techniques for stochastic simulation. Topics will include random number generation, the regenerative method, variance reduction techniques, the quasi-Monte Carlo approach, and Markov Chain Monte Carlo algorithms. Methodology will be illustrated on examples drawn from communications, transportation and manufacturing systems as well as financial engineering.

Basic textbooks:
Asmussen, S. and P. W. Glynn *Stochastic Simulation: Algorithms and Analysis*, Springer, 2007 (ISBN-13: 978-0-387-30679-7).
Fishman, G. S. *Monte Carlo: Concepts, Algorithms & Applications*, Springer-Verlag, 1996 (ISBN 0-387-94527-X).
Glasserman, P. *Monte Carlo Methods in Financial Engineering*, Springer, 2004 (ISBN 0-387-00451-3).
Law, A. M., and W. D. Kelton *Simulation, Modeling and Analysis*, 3rd edition, McGraw Hill, 2000 (ISBN 0-07-059292-6).

Note: I will not follow any particular textbook. The above references are recommended as they contain most of the material that I would like to cover. The first two books are general sources with applications illustrated in a variety of fields including physics, queueing theory, graph/combinatorial theory, and manufacturing systems. However, I would recommend the first book as it is the closest in spirit to the goal of the course. Students may opt to acquire the third instead if they wish to concentrate exclusively on applications in quantitative finance. The last book contains detailed illustrations of discrete-event simulation.

Additional references will be used and will be announced as we progress through the topics. They will be mostly in the form of papers.

Pre-requisites:
Students are expected to be comfortable with basic notions of probability and

statistics. Particularly important are concepts of stochastic processes (Markov process, renewal process, etc.) and standard convergence results for basic statistical estimators (laws of large numbers and central limit theorem).

Grading:
Homework 20% (to be assigned every other week, approximately); Mid-term 30%, final project 50%.

Bibliographical Sources for Lectures
(may be edited as we progress through the semester)
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1. General:
   A standard and frequently updated source is the annual *Proceedings of the Winter Simulation Conference*. It contains tutorials as well as recent advances in simulation methodology and applications.

2. Uniform and non-uniform random number generation topics/issues:

   - Knuth, D. (1981), *The Art of Computer Programming, vol. 2, Semi-Numerical Algorithms*, 2nd edition, Chap. 3, Addison Wesley, Reading, MA.
   - L'Ecuyer, P. (2001), Software for uniform random number generation: distinguishing the good and the bad, *Proceedings of the 2001 Winter Simulation Conference*, pp 95-105, IEEE Press.
   - Park, S. K. and K. W. Miller (1988), Random number generators: good ones are hard to find, *Comm. A.C.M.*, 31, pp. 1192-1201.
   - Hömann, W., J. Leydold and G. Derflinger (2004), *Automatic Nonuniform Random Variate Generation*, Springer.
   - C Code for standard uniform and non-uniform random generators can be found at:
     http://statmath.wu-wien.ac.at/arvag/
   - Marsaglia, G. (2003), Seeds for random number generators, *Comm. A.C.M.*, 46, pp. 90-93.
   - Testing uniform random number generators. The most widely used set of tests (structural as well as statistical) is the *DIEHARD* battery of Marsaglia, which can be found at http://stat.fsu.edu/ geo/diehard.html.
   - To exploit parallel processing capabilities when generating random numbers, see:
     - Agarwal, et al. (2002), Fast pseudo-random number generators with modulus 2^k or $2^k - 1$ using fused multiply-add, *IBM J. Research Dev.*, 46, January 2002.

3. The jackknife and bootstrap approaches in statistical output analysis:

   - Efron, B. (1982) *The Jackknife, the Bootstrap, and Other Resampling Plans*, SIAM-CMBS-NSF Series.
   - Efron, B. and R. Tibshirani (1986), Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy, *Statistical Science*, 1, 54-77.
   - Efron, B. and R. Tibshirani (1993), *An Introduction to the Bootstrap*, Chapman and Hall.

4. Variance Reduction Techniques:
   Law and Kelton, Chap. 11,
   Glasserman, Chap. 4.
   Fishman, Chap. 4.
   Chap. 2 in Bratley, P. B.L. Fox, and L. Shrage (1987), *A Guide to Simulation*, 2nd ed., Springer-Verlag, New York.

5. Markov Chain Monte Carlo

   - Fishman, §5.14.
   - Hastings (1970), Monte Carlo sampling methods using Markov chains and their applications, *Biometrika*, 57, 97-109.
   - Robert, C. and G. Casella, (1999), *Monte Carlo Statistical Methods*, Springer Verlag (1999), Springer-Verlag, New York.
   - MCMC central source: www.statslab.cam.ac.uk/ mcmc

6. Quasi-Monte Carlo Approach:

   - Glasserman, Chap. 5.
   - Niederreiter, H. (1992), *Random Number Generation and Quasi-Monte Carlo Methods*, CBMS-NSF Regional Conferences Series in Applied Mathematics, 63, SIAM.
   - L'Ecuyer, P. (2003), Quasi-Monte Carlo Methods for Simulation, *Proceedings of the 2003 Winter Simulation Conference*, pp 81-89, IEEE Press.
   - L'Ecuyer, P. and C. Lemieux (2000), Variance reduction via lattice rules, *Management Science*, 46, 1214-1235.