

## **Monte Carlo Methods**

**Kevin Lin**

Description: This is an introduction to the basics of Monte Carlo algorithms, some of their main applications, and their mathematical analysis. The main topics will include:

- Direct sampling techniques
- Discrete event simulation
- Continuous-time Markov chains (Gillespie algorithm)
- Markov chain Monte Carlo (MCMC)
- MCMC error analysis and the Kubo formula
- Importance sampling and rare event simulation

Examples will be drawn from fields including statistical physics, chemistry, Bayesian statistics, and others (depending in part on student interest).

Time permitting, more advanced topics may also be covered. Some possible topics include:

- Sequential Monte Carlo / filtering
- Rare event simulations
- Multiscale acceleration techniques
- Numerical methods for stochastic differential equations
- Exact sampling
- Variance reduction

This course should be appropriate for graduate students from applied mathematics, physical sciences, engineering, statistics, and computer science.

Prerequisites: basic probability, at the level of Math 464 or equivalent; linear algebra at the level of Math 410; some exposure to the theory of Markov chains, e.g., Math 468 or equivalent; and ability (or willingness to learn) to program in a suitable language such as Matlab, Python, R, Java, C, etc.

Grading: This being a topics course, grading will be mainly based on a small project. I may also assign some homework problems throughout the semester.

Textbook: none required at this time

Main references:

- M H Kalos and P A Whitlock, *Monte Carlo Methods*, Wiley 2008
- J S Liu, *Monte Carlo Strategies in Scientific Computing*, Springer 2008
- A D Sokal, "Monte Carlo methods in statistical mechanics: foundations and new algorithms," *Functional Integration (Cargèse, 1996)*, 131–192, NATO Adv. Sci. Inst. Ser. B Phys., 361, Plenum, New York, 1997

Some additional references:

- A J Chorin and O H Hald, *Stochastic Tools in Mathematics and Science*, Springer 2009
- J M Handscomb and D C Hammersley, *Monte Carlo Methods*, Methuen 1965