Stat 202C: Monte Carlo Methods for Optimization

MW 2-3:15 pm, Spring 2018, Math Science 5128

[syllabus.pdf]

Course Description

This graduate level course introduces Monte Carlo methods for simulation, optimization, estimation, learning and complex landscape visualization, including: Importance sampling; Sequential importance sampling; Markov chain Monte Carlo (MCMC) sampling techniques including Gibbs samplers, Metropolis/Hastings and various improvements; Simulated annealing; Exact sampling techniques; Convergence analysis; Data augmentation; Cluster sampling, such as Swendsen-Wang and SW-cuts; Hamiltonian and Langevin Monte Carlo; Equi-energy and multi-domain sampler; and Techniques for mapping complex energy landscapes.

Prerequisites

- Stat 202B Matrix Algebra and Optimization.
- People who didn't take 202B before may still take this class by asking for a PTE# as long as they have background on matrix algebra, probability theory, and programming skills. So far the course had graduate students from a wide range of departments: Statistics, CS, EE, Mechanical Eng., Civil Eng., Bio-Eng., Economics, Management in business school, Urban planing, Politic Science, Social Science, Geophysics, Physics, Chemestry, ...

Textbooks

The lectures will be based on the following book draft.

- Adrian Barbu and Song-Chun Zhu, *Monte Carlo Methods* Springer, Draft 2018 [Draft as handout].

Instructors

- Prof. Song-Chun Zhu, sczhu@stat.ucla.edu, 310-206-8693, office BH 9404, Office Hours: Monday 3:30-5:00pm.
- Teaching assistant Mitch Hill, mkhill@ucla.edu, Office hours: Thursday 3:00-5:00pm at MS 8141 TA room.

Grading Plan: 4 units, letter grades

The grade will be based on four parts

2 homework	20%
3 small projects	45%
Final exam	35%

Tentative List of Topics

Chapter 1, Introduction to Monte Carlo Methods

[Lect1.pdf] PDF files will be distriibuted through CCLE

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1, Monte Carlo methods in science and enginnering
   -- Simulation, estimation, sampling, optimization, learning, and visualization.
2, Topics and issues in Monte Carlo methods
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Chapter 2, Sequential Monte Carlo

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1. Importance sampling and weighted samples
2. Advanced importance sampling techniques
3. Framework for sequential Monte Carlo
      (selection, pruning, resampling, ...)
4. Application: particle filtering in object tracking, Monte Carlo Tree Search
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Chapter 3, Backgrounds on Markov Chains

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1. The transition matrix
2. Topology of transition matrix: communication and period
3. Positive recurrence and invariant measures
4. Ergodicity theorem
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Chapter 4, Metropolis methods and its variants

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1. Metropolis algorithm and the Hastings's generalization
2. Special case: Metropolized independence sampler
3. Reversible jumps and trans-dimensional MCMC
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Chapter 5 Gibbs sampler and its variants

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1. Gibbs sampler
2. generalizations:
    Hit-and-run, Multi-grid, generalized Gibbs, Metropolized Gibbs
3. Data association and data augmentation
4. Slice sampling
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Chapter 6 Clustering sampling

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1. Ising/Potts models
2. Swendsen-Wang and clustering sampling
3. Three interpretations of the SW method
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Chapter 7 Langevin Dynamics

1. Hamiltonian Monte Carlo
2. Langiven dynamics used in machine learning
   Gibbs Reaction and Diffusion equations, Alternative Back-propagation

Chapter 8 Convergence analysis

1. Monitoring and diagnosing convergence
2*. Contraction coefficient
3. Puskin's order
4*. Eigen-structures of the transition matrix
   (Perron-Frobenius theorem, spectral theorem)
5. Geometric bounds
6*. Exact analysis on independence Metropolised Sampler (IMS)
7*. First hitting time analysis and bounds for IMS (paper)
8. Path coupling techniques.
   Bounds for Gibbs sampler and Swendson-Wang algorithm (paper).

* discussed in previous Chapters.

Chapter 9 Exact sampling

1. Coupling from the past CFTP
2. Bounding chains

Chapter 10 Advanced topics

1. Equi-energy and mult-domain sampler
2. Wang-Landau algorithm
3. Attraction-Diffusion Algorithm
4. Mapping the energy landscape and case studies
5. Visualization of object recognition and the image universe
6. Landscapes for curriculum learning