Lecture Notes for "Stochastic Modeling and Computations"

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The course offers a soft and self-contained introduction to modern applied probability covering theory and application of stochastic models. Emphasis is placed on intuitive explanations of the theoretical concepts, such as random walks, law of large numbers, Markov processes, reversibility, sampling, etc., supplemented by practical/computational implementations of basic algorithms. In the second part of the course, the focus shifts from general concepts and algorithms per se to their applications in science and engineering with examples, aiming to illustrate the models and make the methods of solution, originating from physics, chemistry, machine learning, control and operations research, clear.

Subjects for Journal Club Presentations & Reports: (Incomplete) Pool of Options

1. Large Deviation for Multiplicative Processes

Stretching and Rotations of clouds and particles, ordered exponentials, long time statistics of Lyapunov exponents. Cramer/entropy function. http://arxiv.org/abs/cond-mat/0105199

2. The Noisy Channel Coding (Shannon) Theorem

Sec. 9.3 and 10 of [1]

3. Compressed Sensing and its many uses (How l_1 norm promotes sparcity?)

Pick a review from the extended list available at https://en.wikipedia.org/wiki/Compressed_sensing
An original option is http://statweb.stanford.edu/~candes/papers/DecodingLP.pdf

4. Slice Sampling MCMC

See https://en.wikipedia.org/wiki/Slice_sampling. Recommended review is Neal, Radford M. (2003). "Slice Sampling". Annals of Statistics 31 (3): 705767.

5. Simulated Annealing Sampling

Important idea and algorithm allowing to explore seriously non-convex problems – rugged landscape with multiple valleys, saddle points, minima and peaks. The original paper is Kirkpatrick, S.; Gelatt Jr, C. D.; Vecchi, M. P. (1983). "Optimization by Simulated Annealing". Science 220 (4598): 671680. See also https://en.wikipedia.org/wiki/Simulated_annealing and references there in.

6. Hamiltonian MCMC

MCMC which is capable to accelerate sampling by adding additional degrees of freedom - related to controlled inertia/momenta expressed through a Hamiltonian description (from physics) — thus the name. Recommended review http://www.cs.utoronto.ca/~radford/ftp/ham-mcmc.pdf

7. *Irreversible Monte Carlo algorithms for efficient sampling*

The original paper is http://arxiv.org/abs/0809.0916.

8. *Warm Algorithm in Classical and Quantum Statistical Physics*

The original paper is http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=2194&context=physics_faculty_pubs. See also http://wiki.phys.ethz.ch/quantumsimulations/_media/lecture_101007.pdf.

9. *Gillespie algorithm*

Sampling from stochastic equations (Langevin type) which proceeds by jumps. See the original paper Gillespie, Daniel T. (1977). "Exact Stochastic Simulation of Coupled Chemical Reactions". The Journal of Physical Chemistry 81 (25): 23402361 and also check https://en.wikipedia.org/wiki/Gillespie_algorithm.

10. *Sequential Monte Carlo for Importance Sampling & Inference*

Recommended paper https://www.irisa.fr/aspi/legland/ensta/ref/doucet00b.pdf.

11. *Ising models and Other Graphical Models in Image Analysis*

Recommended tutorial https://www.math.ntnu.no/~joeid/TMA4250/image_ana.pdf.

12. *Efficient Exact Inference in Planar Ising Model*

Recommended paper http://arxiv.org/pdf/0810.4401.pdf.

13. *Stochastic Resonances*

Curious physics phenomena important in optics & communications which explains how noise/randomness allows to amplify signal and observe what otherwise would be difficult to detect. Recommended paper is Benzi, R.; Sutera, A.; and Vulpiani, A. "The Mechanism of Stochastic Resonance." J. Phys. A 14, L453-L457, 1981.

14. *Decoding of Low Density Parity Check Codes*

Section 47 of [1].

15. *Analytic and Algorithmic Solution of Satisfiability Problem*

The original paper is http://cacs.usc.edu/education/cs653/Mezard-RSAT-Science02.pdf
See the book of Mezard and Montanari + papers/reviews of Parisi, Mezard and Zechina.

16. *Neural Network Learning*

Part V of [1].

17. Jackson Networks of Queues

Recommended paper is Kelly, F. P. (Jun 1976). "Networks of Queues". Advances in Applied Probability 8 (2): 416432. See alos `https://en.wikipedia.org/wiki/Jackson_network` and references there in.

18. Path Integral Control & Reinforcement Learning

Recommended review `http://www.snn.ru.nl/~bertk/kappen_granada2006.pdf`

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[1] D. J. C. Mackay, *Information theory, inference, and learning algorithms*. Cambridge: Cambridge University Press, 2003. [Online]. Available: http://www.inference.phy.cam.ac.uk/itprnn/book.html