Syllabus 2016 Computer and Mathematical Sciences

Physical Fluctuomatics

Japanese

Basic information

held this year:	yes
instructor(s)	Prof. Kazuyuki Tanaka
room	Middle Lecture Room, Second Floor of the Building of Graduate School of Information Sciences
schedule	The first half year (Thursday) 13:00–14:30
begins on:	04/14

Objectives and outline

Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.

Class plan

1st Review of probabilistic information processing
2nd Mathematical Preparations (1): Probability and statistics
3rd Mathematical Preparations (2): Variational principles and orthonomal expansion of descrite functions
4th Maximum likelihood estimation and EM algorithm
5th Probabilistic information processing by Gaussian graphical model (1)
6th Probabilistic information processing by Gaussian graphical model (2)
7th Belief propagation (1)
8th Belief propagation (2)
9th Belief propagation (3)
10th Belief propagation (4)
11th Probabilistic image processing by means of physical models
12th Bayesian network and belief propagation in statistical inference
13th Quantum-mechanical extentions of probabilistic information processing
14th Complex networks and physical fluctuations
15th Examinations

Evaluation

Evaluation is performed comprehensively based on final examination results (80%) and submitted reports (20%).

Textbook(s)

Examples
1. K. Tanaka: Statistical-mechanical approach to image processing (Topical Review), Journal of Physics A: Mathematical and General, vol.35, no.37, pp.R81-R150, 2002.
2. H. Nishimori: Statistical Physics of Spin Glasses and Information Processing, ---An Introduction, Oxford University Press, 2001.
3. M. Opper and D. Saad D (eds): Advanced Mean Field Methods --- Theory and Practice, MIT Press, 2001.
4. C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006.
5. M. J. Wainwright and M. I. Jordan: Graphical Models, Exponential Families, and Variational Inference, now Publishing Inc, 2008.
6. M. Mezard, A. Montanari: Information, Physics, and Computation, Oxford University Press, 2009.
7. K. P. Murphy: Machine Learning: A Probabilistic Perspective, MIT Press, 2012.

Web site

Presentation Slides http://www.smapip.is.tohoku.ac.jp/~kazu/PhysicalFluctuomatics/2016/
Markov Random Fields and Belief Propagations http://www.smapip.is.tohoku.ac.jp/~kazu/SMAPIP-KazuKazu/index-e.html
Fundamental Programs of Markov Random Fields and Belief Propagations
http://www.smapip.is.tohoku.ac.jp/~kazu/SMAPIP-KazuKazu/program-e.html

Office hours

Students should visit my office after taking an appointment by e-mail (kazu [at mark] smapip.is.tohoku.ac.jp).

Other information

Differential and integral calculus, complex analysis and Fourier analysis are necessary as background knowledge. This lecture is presented in Japanese. English version slides are available in the following wekbape http://www.smapip.is.tohoku.ac.jp/~kazu/PhysicalFluctuomatics/2016/

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