CMPE 58K, Sp Top in CmpE: Bayesian Statistics and Machine Learning

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Course Homepage

`http://www.cmpe.boun.edu.tr/courses/cmpe58K/fall2009/`

Catalog Description

Machine learning approaches using Bayesian statistics. Graphical models, directed and undirected models, learning and inference, Hidden Markov Models (HMM's), Linear Dynamical Systems, message passing algorithms, Junction Tree, factor graphs, sum-product, hierarchical Bayesian modeling, Expectation-Maximisation, Variational Approximation techniques

Course Description

In the Bayesian paradigm, data is viewed as realizations from highly structured probabilistic models. Once a model is constructed, several interesting problems such as feature extraction, pattern recognition, retrieval, sensor fusion, coding, network analysis, classification, restoration, tracking, source separation or model selection can be formulated as Bayesian inference problems. In this context, graphical models provide a "language" to construct models for quantification of prior knowledge. Unknown parameters in this specification are estimated by probabilistic inference. Often, however, the problem size poses an important challenge and in order to render the approach feasible, specialized inference methods need to be tailored to improve the computational speed and efficiency.

The scope of this course is to review the fundamentals of probabilistic models, inference algorithms and associated data structures. We will review directed (Bayesian Networks) and undirected (Markov Random fields), factor graphs and junction trees. In particular, we will review exact inference, approximate deterministic (variational) inference techniques. Stochastic inference techniques are treated in a different course focusing entirely on Monte Carlo computation (offered in Bogazici as CMPE58N).

Our ultimate aim is to provide a basic understanding of probabilistic modeling for machine learning, associated computational techniques such that the research students can orient themselves in the relevant literature and understand the current state of the art.

Topics

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Probability Theory Review, Graphical Models
Bayesian Learning, Probability Distributions,
Construction of Probabilistic models, Hierarchical Modeling, Conjugate Priors,
Sequential Data
Inference in Hidden Markov Models (HMM's),
Multivariate Gaussians, Linear Dynamical Systems (LDS's),
Inference in  LDS, Kalman Filter and Smoother
Approximate inference, Variational Methods, Mean field,
Variational Bayes, ICM
Expectation Maximisation (EM), Bayesian learning in HMM's and LDS's,
Switching state space models, Nonlinear Dynamic Systems, Changepoint models
Exact Inference, Junction Tree, Belief Propagation, Sum Product algorithm
Advanced topics: Nonparametric Bayesian models, Dirichlet Process Mixtures
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Who should take this course

This course teaches statistical techniques for modeling real world phenomena and dealing with uncertainty for making sense of data. As analysis of data is central in several application domains, techniques covered in this class have a quite wide applicability. Whilst our coverage is not exhaustive, in the past, students from several disciplines with following interests have benefited from the material

- Computer Engineering
  - Machine Learning, Pattern Recognition,
  - Computer Vision, Machine Listening
  - Artificial Intelligence (Expert Systems, Dealing with uncertainty)
  - Robotics (Novelty detection, tracking, navigation)
  - Cognitive Science (modelling human behaviour)
  - Software Engineering, (modelling software development and testing)
  - Network design (Statistical analysis of structure, dynamics and evolution of networks)
- Electrical Engineering, Biomedical Engineering,
  - Statistical Signal Processing
  - Time series analysis, Spectral estimation
  - Source separation, Denoising, Imaging, Speech processing
  - Dynamical Systems, Control,
  - Information theory
- Industrial Engineering,
  - Probabilistic Models, Decision support systems
- Chemical Engineering
  - Bioinformatics, analysis of gene expression data
- Physics, Mathematics
  - Statistical mechanics
  - Applications of probability and graph theory
  - Financial mathematics

Graduate students and interested senior undergraduates are welcome to take the course with or without credit.

Textbooks

Handouts and relevant chapters from the following books:

- Pattern Recognition and Machine Learning,
  Christopher Bishop
  Hardcover: 738 pages
  Publisher: Springer-Verlag New York Inc.; New Ed edition (1 Feb 2008)
  Language English
  ISBN-10: 0387310738
  ISBN-13: 978-0387310732
  `http://research.microsoft.com/~cmbishop/PRML/index.htm`
- Information Theory, Inference, and Learning Algorithms
  David MacKay
  Hardback: 640 pages
  Publisher: Cambridge University Press – fourth printing (March 2005)
  ISBN-10: 0521642981
  ISBN-13: 978-0521642989 `http://www.inference.phy.cam.ac.uk/mackay/itprnn/book.html`

- Machine Learning, A Probabilistic Approach,
  David Barber
  Online, to be published by the Cambridge University Press
  `http://web4.cs.ucl.ac.uk/staff/D.Barber/courses/mlgm_epfl_book.pdf`

Prerequisite

CmpE 343 (Introductory Probability and Statistics) or equivalent

Administrative (Tentative)

- Grading
  - % 30 Midterm
  - % 70 Assignments, Final Project and Report
- Total Credits 3