Engineering Tripos Part IIB, 4F13: Probabilistic Machine Learning, 2018-19

Module Leader

Prof C Rasmussen [1]

Lecturers

Prof C Rasmussen

Timing and Structure

Michaelmas term. 14 lectures + 2 examples classes. Assessment: 100% coursework

Prerequisites

3F3 useful

Aims

The aims of the course are to:

- introduce students to basic concepts in machine learning, focusing on statistical methods for supervised and unsupervised learning.

Objectives

As specific objectives, by the end of the course students should be able to:

- demonstrate a good understanding of basic concepts in statistical machine learning.
- apply basic ML methods to practical problems.

Content

Machine learning (ML) is an interdisciplinary field focusing on both the mathematical foundations and practical applications of systems that learn, reason and act. The goal of machine learning is to automatically extract knowledge from observed data for the purposes of making predictions, decisions and understanding the world.

The aim of this module is to introduce students to basic concepts in machine learning, focusing on statistical methods for supervised and unsupervised learning. The module will be structured around three recent illustrative successful applications: Gaussian processes for regression and classification, Latent Dirichlet Allocation models for unsupervised text modelling and the TrueSkill probabilistic ranking model.

- Linear models, maximum likelihood and Bayesian inference
- Gaussian distribution and Gaussian process
- Model selection
- The Expectation Propagation (EP) algorithm
- Latent variable models

- The Expectation Maximization (EM) algorithm
- Dirichlet Distribution and Dirichlet Process
- Variational inference
- Generative models, graphical models: Factor graphs

Lectures will be supported by Octave/MATLAB demonstrations.

A detailed syllabus and information about the coursework is available on the course website: http://mlg.eng.cam.ac.uk/teaching/4f13/ [2]

Coursework

Coursework	Format	Due date & marks
[Coursework activity #1 Gaussian Processes] Coursework 1 brief description Learning objective: • To gain experience in Bayesian Gaussian Process (GP) regression. • To familiarise yourself with the GPML toolbox. • To understand properties of covariance functions. • To perform hyperparameter learning. • To understand how model selection can be done using the marginal likelihood.	Individual/group Report / Presentation anonymously marked for MPHIL/MLSALT & Undergraduates Nonanonymously marked for PhDs	day during te Fri week 5 [20/60]
[Coursework activity #2 Probabilistic Ranking] Coursework 2 brief description Learning objective: • To understand inference in continuous probabilistic models represented as factor graphs. • To understand the Gibbs sampling algorithm and gain experience with using Markov chain Monte Carlo (MCMC) for inference. • To understand message passing on (loopy) factor graphs. • To learn how to construct approximate messages using Expectation Propagation (EP).	Individual Report Anonymously marked for MPHIL/MLSALT & Undergraduates Nonanonymously marked for PhDs	Fri week 7 [20/60]
[Coursework activity #3 Latent Dirichlet Allocation models or documents] Coursework 3 brief description Learning objective: • To understand unsupervised learnign in discrete graphical models for documents. • To develop an understanding of graphical models with more complex latent structure. • To understnad and apply the Expectation Maximization (EM) and Gibbs sampling algorithms.	Individual Report Anonymously marked for MPHIL/MLSALT & Undergraduates Nonanonymously marked for PhDs	Fri week 9 [20/60]

Coursework	Format	Due date & marks
• To perform unsupervised learning using Latent Dirichlet Allocation model on a collection of documents.		

Booklists

Please see the Booklist for Group F Courses [3] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [4].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [5] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

P8

Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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Links
[1] mailto:cer54@cam.ac.uk
[2] http://mlg.eng.cam.ac.uk/teaching/4f13/
[3] https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=55951
[4] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations
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