Engineering Tripos Part IIA, 3F8: Inference, 2019-20

Leader
Dr R.E. Turner [1]

Lecturer
Dr R.E. Turner, Dr Jose Miguel Hernandez-Lobato

Lab Leader
Dr Jose Miguel Hernandez-Lobato

Timing and Structure
Lent Term.

Prerequisites
3F3 Statistical Signal Processing

Aims
The aims of the course are to:

- Provide a thorough introduction into the topic of statistical inference including maximum-likelihood and Bayesian approaches
- Introduce inference algorithms for regression, classification, clustering and sequence modelling
- Introduce basic concepts in optimisation, dynamic programming and Monte Carlo sampling

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

- Understand the use of maximum-likelihood and Bayesian inference and the strengths and weaknesses of both approaches.
- Implement methods to solve simple regression, classification, clustering and sequence modelling problems.
- Implement simple optimisation methods (gradient and coordinate descent, stochastic gradient descent), dynamic programming (Kalman filter or Viterbi decoding) and Monte Carlo sampling.

Content

Introduction to inference (2L)

- Decision theory, estimation
Regression (3L)
- Revision of properties of Gaussian probability density
- Maximum likelihood and Bayesian fitting of Gaussians
- Linear regression and non-linear regression

Classification (2L)
- Classification problems
- Logistic regression probabilistic model
- Training logistic regression using optimisation
- Stochastic optimisation methods
- Non-linear feature expansions for logistic regression

Dimensionality Reduction (2L)
- Principal component analysis as minimising reconstruction cost
- Principal component analysis as inference

Clustering (3L)
- What is clustering
- The k-means algorithm
- Gaussian Mixture Models
- The Expectation Maximisation (EM) Algorithm

Sequence models (3L)
- Sequence modelling problems
- Markov Models and Hidden Markov models
- Inference in Hidden Markov Models using dynamic programming

Very Basic Monte Carlo (introduced through the lectures above)
- Simple Monte Carlo

Further notes
Lecture allocations above are approximate.

Coursework
Title: Logistic Regression for Binary Classification

To implement an algorithm for performing classification, called logistic regression, using gradient descent optimisation.

Learning objectives:
- understand the logistic regression model through visualising predictions
- how to apply maximum likelihood and MAP fitting using optimisation
- how to implement gradient ascent
- understand how feature expansions can turn linear methods into non-linear methods

Practical information:
- Sessions will take place in the DPO, during week(s) [TBD].
- This activity involves a small amount of preliminary work [estimated duration 1hr].

Full Technical Report:
Students will have the option to submit a Full Technical Report.

**Booklists**

There is no required textbook. However, the material covered is treated excellent recent text books:


David Barber *Bayesian Reasoning and Machine Learning* [3], Cambridge University Press (2012), available freely on the web.

Christopher M. Bishop *Pattern Recognition and Machine Learning* [4], Springer (2006)


**Examination Guidelines**

Please refer to [Form & conduct of the examinations](http://teaching.eng.cam.ac.uk/content/form-conduct-examinations) [6].

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**Links**

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[3] [http://www.cs.ucl.ac.uk/staff/d.barber/brml](http://www.cs.ucl.ac.uk/staff/d.barber/brml)
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