ES98E-15 Scientific Machine Learning

24/25

Department
School of Engineering
Level
Taught Postgraduate Level
Module leader
James Kermode
Credit value
15
Module duration
10 weeks
Assessment
60% coursework, 40% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

This module provides students with knowledge in the modern field of scientific machine learning, which is a fusion of scientific computing and machine learning.

Module aims

Understand how to use a variety of statistical and machine learning techniques to train models which combine data-driven and mechanics models and assess their ability to make useful predictions.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

- Bayesian linear regression and enhancements to it such as automatic relevance determination
- Gaussian process regression and enhancements such as sparse GP regression and the Kennedy-O'Hagan approach to model discrepancy.
- Kernel based ML-techniques including SVM and applications of reproducing kernel Hilbert

spaces
- Dimensionality reduction as a tool for data analysis (PCA, kPCA, active subspaces)
- Advanced state space models such as the ensemble Kalman filter
- Neural networks and deep neural networks
- Neural differential equations and physics informed neural networks
- Advanced approximate Bayesian inference: variational inference, expectation maximisation, etc.

Learning outcomes

By the end of the module, students should be able to:

- Understand and interpret the application of Bayesian inference to infer model parameters from data
- Apply Gaussian process regression to build surrogate models for computational codes and evaluate the results
- Apply deep neural networks to accelerate scientific computing and interpret the results
- Synthesise neural network and mechanistic models and apply them to perform scientific machine learning
- Evaluate advanced inference techniques such as variational inference work and critique when they can be applied
- Recognise, formulate, analyse and interpret machine learning solutions to scientific problems
- Critique the application of machine learning methods to cutting edge problems in scientific computing

Indicative reading list

Bishop, Pattern Recognition and Machine Learning
MacKay, Information Theory, Pattern Recognition and Learning Algorithms
Rasmussen and Willians, Gaussian Processes for Machine Learning
Gelman, Bayesian Data Analysis
Hastie, The Elements of Statistical Learning: Data Mining, Inference and Prediction

View reading list on Talis Aspire

Interdisciplinary

The MSc programme will recruit students with backgrounds across the physical and mathematical sciences, including engineering, and will provide an interdisciplinary perspective on predictive modelling.

Scientific machine learning is a fusion of scientific computing and machine learning, drawing from mathematics, statistics and the modelling of physical phenomena across a wide range of application domains.

Subject specific skills

- Machine learning
- Computational statistics
- Predictive modelling
- Fusion of advanced data analysis and mathematical modelling techniques

Transferable skills

- Data analysis and modelling
- Oral presentation skills
- Scientific computing

Study

Study time

Type	Required
Lectures	10 sessions of 2 hours (13%)
Supervised practical classes	8 sessions of 2 hours (11%)
Private study	114 hours (76%)
Total	150 hours

Private study description

Students will work independently to complete the weekly assignments outside of the workshops and to prepare for the viva.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group D

	Weighting	Study time	Eligible for self-certification
Computer Laboratory Assignments	60%		Yes (extension)

6 x 1 page assignments based upon lecture topic and computer laboratory work

	Weighting	Study time	Eligible for self-certification
Oral Examination	40%		No

1. Student presentation of how scientific machine learning is relevant to their research project and other interests
2. Unseen questions, based on a pre-circulated list of general topics aligned with the lectures and laboratory sessions

Feedback on assessment

Annotation of computer workbooks with feedback on individual questions
Written feedback from examiners of viva voce exam

Past exam papers for ES98E

Availability

Courses

This module is Core for:

- TESA-H1B1 Postgraduate Taught Predictive Modelling and Scientific Computing
  - Year 1 of H1B1 Predictive Modelling and Scientific Computing
  - Year 2 of H1B1 Predictive Modelling and Scientific Computing