MA3K1-15 Mathematics of Machine Learning

20/21

Department
Warwick Mathematics Institute
Level
Undergraduate Level 3
Module leader
Martin Lotz
Credit value
15
Module duration
10 weeks
Assessment
Multiple
Study location
University of Warwick main campus, Coventry

Description

Introductory description

N/A

Module web page

Module aims

The aim of this course is to introduce Machine Learning from the point of view of modern optimization and approximation theory.

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.

Fundamentals of statistical learning theory

- Regression and classification
- Empirical risk minimization and regularization

- Concentration inequalitites
- VC theory
- Rademacher complexity and covering numbers

Optimization

- Convexity
- Optimality conditions, Lagrange duality, KKT conditions
- Quadratic optimization and support vector machines
- Gradient descent - Acceleration
- Proximal gradient methods
- Stochastic gradient descent

Deep Learning

- Neural networks
- Convolutional neural networks
- Universal approximation
- Adversarial perturbations
- Generative adversarial networks (GAN)
- Accuracy and stability
- Recurrent neural networks
- Applications

Learning outcomes

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

- Describe the problem of supervised learning from the point of view of function approximation, optimization, and statistics.
- Identify the most suitable optimization and modelling approach for a given machine learning problem.
- Analyse the performance of various optimization algirthms from the point of view of computational complexity (both space and time) and statistical accuracy.
- Implement a simple neural network architecture and apply it to a pattern recognition task.

Indicative reading list

1. Beck, Amir. First-Order Methods in Optimization. Vol. 25. SIAM, 2017.
2. Vapnik, Vladimir. The nature of statistical learning theory. Springer, 2013.
3. Cucker, Felipe, and Ding Xuan Zhou. Learning theory: an approximation theory viewpoint. Vol. 24. Cambridge University Press, 2007.
4. Higham, Catherine F., and Desmond J. Higham. "Deep Learning: An Introduction for Applied Mathematicians." arXiv preprint arXiv:1801.05894 (2018).
5.Yurii Nesterov, Lectures on Convex Optimization, Springer, 2018
6.Aaron Courville, Ian Goodfellow, and Yoshua Bengio, Deep Learning, MIT Press, 2016
7.Gábor Lugosi, Pascal Massart, and Stéphane Boucheron, Concentration Inequalities,

OUP, 2013

Subject specific skills

At the end of this course, the students will be able to apply state-of-the-art optimization methods to machine learning tasks, and evaluate their performance.

Transferable skills

Students will acquire key reasoning and problem solving skills which will empower them to address new problems with confidence.

Study

Study time

Type	Required
Lectures	30 sessions of 1 hour (20%)
Private study	120 hours (80%)
Total	150 hours

Private study description

Review lectured material, work on set exercises and attend support classes.

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group D1

	Weighting	Study time
Assignments	15%	
In-person Examination	85%	

	Weighting	Study time

- Answerbook Gold (24 page)

Assessment group R

	Weighting	Study time
In-person Examination - Resit	100%	

- Answerbook Gold (24 page)

Feedback on assessment

Marked coursework and exam feedback.

Past exam papers for MA3K1

Availability

Courses

This module is Optional for:

- Year 1 of TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
- UCSA-G4G1 Undergraduate Discrete Mathematics
  - Year 3 of G4G1 Discrete Mathematics
  - Year 3 of G4G1 Discrete Mathematics
- Year 3 of UCSA-G4G3 Undergraduate Discrete Mathematics
- Year 4 of UCSA-G4G2 Undergraduate Discrete Mathematics with Intercalated Year
- USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
  - Year 3 of G300 Mathematics, Operational Research, Statistics and Economics
  - Year 4 of G300 Mathematics, Operational Research, Statistics and Economics
- Year 3 of UMAA-GL11 Undergraduate Mathematics and Economics

This module is Core option list B for:

- UMAA-GV17 Undergraduate Mathematics and Philosophy
  - Year 3 of GV17 Mathematics and Philosophy
  - Year 3 of GV17 Mathematics and Philosophy
  - Year 3 of GV17 Mathematics and Philosophy
- Year 3 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Option list A for:

- Year 1 of TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- TMAA-G1P0 Postgraduate Taught Mathematics
  - Year 1 of G1P0 Mathematics (Taught)
  - Year 1 of G1P0 Mathematics (Taught)
- Year 1 of TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
  - Year 3 of G105 Mathematics (MMath) with Intercalated Year
  - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G100 Undergraduate Mathematics (BSc)
  - Year 3 of G100 Mathematics
  - Year 3 of G100 Mathematics
  - Year 3 of G100 Mathematics
- UMAA-G103 Undergraduate Mathematics (MMath)
  - Year 3 of G100 Mathematics
  - Year 3 of G103 Mathematics (MMath)
  - Year 3 of G103 Mathematics (MMath)
  - Year 4 of G103 Mathematics (MMath)
  - Year 4 of G103 Mathematics (MMath)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
  - Year 3 of G106 Mathematics (MMath) with Study in Europe
  - Year 4 of G106 Mathematics (MMath) with Study in Europe
- UPXA-GF13 Undergraduate Mathematics and Physics (BSc)
  - Year 3 of GF13 Mathematics and Physics
  - Year 3 of GF13 Mathematics and Physics
- UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
  - Year 3 of FG31 Mathematics and Physics (MMathPhys)
  - Year 3 of FG31 Mathematics and Physics (MMathPhys)
- Year 4 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 4 of UMAA-G101 Undergraduate Mathematics with Intercalated Year
- USTA-Y602 Undergraduate Mathematics,Operational Research,Statistics and Economics
  - Year 3 of Y602 Mathematics,Operational Research,Stats,Economics
  - Year 3 of Y602 Mathematics,Operational Research,Stats,Economics
- Year 4 of USTA-Y603 Undergraduate Mathematics,Operational Research,Statistics,Economics (with Intercalated Year)

This module is Option list B for:

- Year 1 of TMAA-G1PE Master of Advanced Study in Mathematical Sciences
- Year 3 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 4 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)
- USTA-GG14 Undergraduate Mathematics and Statistics (BSc)
  - Year 3 of GG14 Mathematics and Statistics
  - Year 3 of GG14 Mathematics and Statistics
- Year 4 of USTA-GG17 Undergraduate Mathematics and Statistics (with Intercalated Year)

This module is Option list E for:

- USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics
    - Year 3 of G30D Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
    - Year 4 of G30D Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
- USTA-G301 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics (with Intercalated
    - Year 3 of G30H Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)
    - Year 5 of G30H Master of Maths, Op.Res, Stats & Economics (Statistics with Mathematics Stream)