UNSW Course Outline

MATH5191 Mathematical Optimization for Data Science - 2024

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General Course Information

Course Code : MATH5191
Year : 2024
Term : Term 3
Teaching Period : T3
Is a multi-term course? : No
Faculty : Faculty of Science
Academic Unit : School of Mathematics & Statistics
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Postgraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

The course covers theoretical foundations necessary for the in-depth understanding of modern

optimisation methods for data science. The optimisation methods are presented in the context of relevant applications, such as the training of artificial neural networks and data classification. The methods discussed in the course include (stochastic) gradient descent, projection and splitting techniques. The course prepares students for confident application of modern numerical methods to problems in data science and helps them build sufficient mastery of optimisation tools and techniques for designing and implementing tailored methods for solving new problems.

Course Aims

- Introduce major mathematical ideas behind modern optimisation techniques used in data science, such as convex and nonconvex (continuous) optimisation problems, first-order methods, splitting and projection techniques, stochastic optimisation.
- Discuss the considerations contributing to complexity analysis of optimisation problems and algorithms in the context of data science, such as the problem's size and structure, accuracy and efficiency requirements, advantages and limitations of different optimisation techniques, and different perspectives on convergence and (iteration) complexity.
- Place optimisation techniques in the context of major data science applications such as the training of artificial neural networks and data classification, addressing the appropriate choice of numerical methods and their limitations.
- Introduce the students to professional communication styles in the area of optimisation for data science, in particular mapping the ideas and terminology used in different fields. Help students develop effective communication strategies within the topic.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : State and explain fundamental mathematical principles behind the optimisation techniques used in data science.
CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.
CLO3 : Apply standard optimisation techniques to specific problems and estimate their efficiency taking into consideration the problem's parameters and computational constraints. Modify standard methods or design new optimisation techniques to suit specific problems.
CLO4 : Demonstrate competence in mathematical presentation and communication skills, support decisions using mathematical argument and references.
CLO5 : Critically evaluate emerging methods and applications, by comparing the new approaches to well-known techniques, identifying strengths, disadvantages and knowledge gaps.

Course Learning Outcomes	Assessment Item
CLO1 : State and explain fundamental mathematical principles behind the optimisation techniques used in data science.	• Homework assignment • Final Exam • Quiz
CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.	• Individual project • Homework assignment • Final Exam • Quiz
CLO3 : Apply standard optimisation techniques to specific problems and estimate their efficiency taking into consideration the problem's parameters and computational constraints. Modify standard methods or design new optimisation techniques to suit specific problems.	• Individual project • Homework assignment • Final Exam
CLO4 : Demonstrate competence in mathematical presentation and communication skills, support decisions using mathematical argument and references.	• Individual project • Homework assignment • Final Exam
CLO5 : Critically evaluate emerging methods and applications, by comparing the new approaches to well-known techniques, identifying strengths, disadvantages and knowledge gaps.	• Individual project

Learning and Teaching Technologies

Moodle - Learning Management System | Blackboard Collaborate | Echo 360

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Homework assignment Assessment Format: Individual	20%	Due Date: Week 7: 21 October - 27 October
Final Exam Assessment Format: Individual	50%	
Quiz Assessment Format: Individual	15%	Due Date: Week 3: 23 September - 29 September
Individual project Assessment Format: Individual	15%	Due Date: Week 8: 28 October - 03 November

Assessment Details

Homework assignment

Assessment Overview

A homework assignment that allows the students to apply the knowledge they learned in this course. The assignment may include mathematical reasoning, practical calculations and a coding component. There will be starred questions in the assignments which indicate the material that requires advanced mathematical understanding or critical analysis. Students in the PG version version (MATH 5191) are expected to show satisfactory performance on starred questions. Students will receive detailed feedback on their work within 2 weeks from submission.

Course Learning Outcomes

- CLO1 : State and explain fundamental mathematical principles behind the optimisation techniques used in data science.
- CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.
- CLO3 : Apply standard optimisation techniques to specific problems and estimate their efficiency taking into consideration the problem's parameters and computational constraints. Modify standard methods or design new optimisation techniques to suit specific problems.
- CLO4 : Demonstrate competence in mathematical presentation and communication skills, support decisions using mathematical argument and references.

Generative AI Permission Level

Simple Editing Assistance

In completing this assessment, you are permitted to use standard editing and referencing functions in the software you use to complete your assessment. These functions are described below. You must not use any functions that generate or paraphrase passages of text or other media, whether based on your own work or not.
If your Convenor has concerns that your submission contains passages of AI-generated text or media, you may be asked to account for your work. If you are unable to satisfactorily demonstrate your understanding of your submission you may be referred to UNSW Conduct & Integrity Office for investigation for academic misconduct and possible penalties.
For more information on Generative AI and permitted use please see here.

If you are using AI to prepare your homework assignment, please provide a clear statement on

how exactly the AI was used in your work.

Final Exam

Assessment Overview

Final examination, 2 hours, where students are required to answer a set of questions in writing. There will be starred questions in the assignments which indicate the material that require advanced mathematical understanding or critical analysis. Students in the PG version version (MATH 5191) are expected to show satisfactory performance on starred questions.

Course Learning Outcomes

- CLO1 : State and explain fundamental mathematical principles behind the optimisation techniques used in data science.
- CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.
- CLO3 : Apply standard optimisation techniques to specific problems and estimate their efficiency taking into consideration the problem's parameters and computational constraints. Modify standard methods or design new optimisation techniques to suit specific problems.
- CLO4 : Demonstrate competence in mathematical presentation and communication skills, support decisions using mathematical argument and references.

Generative AI Permission Level

No Assistance

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Quiz

Assessment Overview

This online quiz assesses basic understanding of optimisation principles applied to data science learned in the first 2 weeks of the course and allows to provide early feedback on students' performance in the course. This quiz will be scheduled in week 3. Overall feedback addressing the most common errors and misconceptions will be provided to within a week after completion of the quiz.

Course Learning Outcomes

- CLO1 : State and explain fundamental mathematical principles behind the optimisation techniques used in data science.
- CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.

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No Assistance

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Individual project

Assessment Overview

This individual project may involve a study of a novel optimisation method in data science, developing a new application of a known method, or numerical experiments. The students will be required to submit a report on their work during week 8. They will receive detailed feedback on their work within 2 weeks from submission.

Course Learning Outcomes

- CLO2 : Recognise typical optimisation models used in data science and the factors influencing performance of standard optimisation algorithms on these models. Perform mathematical analysis to make an informed choice of an optimisation model and solution technique based on the type of the problem and computational constraints.
- CLO3 : Apply standard optimisation techniques to specific problems and estimate their efficiency taking into consideration the problem's parameters and computational constraints. Modify standard methods or design new optimisation techniques to suit specific problems.
- CLO4 : Demonstrate competence in mathematical presentation and communication skills, support decisions using mathematical argument and references.
- CLO5 : Critically evaluate emerging methods and applications, by comparing the new approaches to well-known techniques, identifying strengths, disadvantages and knowledge gaps.

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If you are using AI to assist your work on this project, please provide a clear statement on how exactly the AI was used in your work.

General Assessment Information

Grading Basis

Standard

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 0 : 2 September - 8 September	Other	N/A
Week 1 : 9 September - 15 September	Lecture	Introduction: Optimisation problems in Data Science
Week 2 : 16 September - 22 September	Lecture	Optimisation Modelling
Week 3 : 23 September - 29 September	Lecture	Gradient Methods
Week 4 : 30 September - 6 October	Lecture	Acceleration and Complexity of First-Order Methods
Week 5 : 7 October - 13 October	Lecture	Stochastic Gradient Descent and other techniques
Week 6 : 14 October - 20 October	Other	N/A
Week 7 : 21 October - 27 October	Lecture	Dealing with Constraints
Week 8 : 28 October - 3 November	Lecture	Nonsmooth Optimisation
Week 9 : 4 November - 10 November	Lecture	Duality and dual methods
Week 10 : 11 November - 17 November	Lecture	Alternative and emerging optimisation techniques
Week 11 : 18 November - 24 November	Other	Study Week

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
	Vera Roshchina					No	Yes

Other Useful Information

Academic Information

Upon your enrolment at UNSW, you share responsibility with us for maintaining a safe, harmonious and tolerant University environment.

You are required to:

- Comply with the University's conditions of enrolment.
- Act responsibly, ethically, safely and with integrity.
- Observe standards of equity and respect in dealing with every member of the UNSW community.
- Engage in lawful behaviour.
- Use and care for University resources in a responsible and appropriate manner.
- Maintain the University's reputation and good standing.

For more information, visit the UNSW Student Code of Conduct Website.

Academic Honesty and Plagarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.
Further information about referencing styles can be located at https://student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits: honesty, trust, fairness, respect, responsibility and courage. At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.
Further information about academic integrity, plagiarism and the use of AI in assessments can be located at:

- The Current Students site,
- The ELISE training site, and
- The Use of AI for assessments site.

The Student Conduct and Integrity Unit provides further resources to assist you to understand

your conduct obligations as a student: https://student.unsw.edu.au/conduct

Submission of Assessment Tasks

Penalty for Late Submissions

UNSW has a standard late submission penalty of:

- 5% per day,
- for all assessments where a penalty applies,
- capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, and
- no permitted variation.

Any variations to the above will be explicitly stated in the Course Outline for a given course or assessment task.

Students are expected to manage their time to meet deadlines and to request extensions as early as possible before the deadline.

Special Consideration

If circumstances prevent you from attending/completing an assessment task, you must officially apply for special consideration, usually within 3 days of the sitting date/due date. You can apply by logging onto myUNSW and following the link in the My Student Profile Tab. Medical documentation or other documentation explaining your absence must be submitted with your application. Once your application has been assessed, you will be contacted via your student email address to be advised of the official outcome and any actions that need to be taken from there. For more information about special consideration, please visit: https://student.unsw.edu.au/special-consideration

Important note: UNSW has a "fit to sit/submit" rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit to do so and cannot later apply for Special Consideration. This is to ensure that if you feel unwell or are faced with significant circumstances beyond your control that affect your ability to study, you do not sit an examination or submit an assessment that does not reflect your best performance. Instead, you should apply for Special Consideration as soon as you realise you are not well enough or are otherwise unable to sit or submit an assessment.

Faculty-specific Information

Additional support for students

- The Current Students Gateway
- Student Support
- Academic Skills and Support
- Student Wellbeing, Health and Safety
- Equitable Learning Services
- UNSW IT Service Centre
- Science EDI Student Initiatives, Offerings and Guidelines

School-specific Information

School of Mathematics and Statistics and UNSW Policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths Stats web site. Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the web site starting at: The School of Mathematics and Statistics assessment policies

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

Special Consideration - Short Extension Policy

The School of Mathematics and Statistics has carefully reviewed its range of assignments and projects to determine their suitability for automatic short extensions as set out by the UNSW Short Extension Policy. Upon comprehensive examination of our course offerings that incorporate these types of assessments, we have concluded that our current deadline structures already accommodate the possibility of unexpected circumstances that may lead students to require additional days for submission. Consequently, the School of Mathematics and Statistics has decided to universally opt out of the Short Extension provision for all its courses, having pre-

emptively integrated flexibility into our assessment deadlines. The decision is subject to revision in response to the introduction of new course offerings. Students may still apply for Special Consideration via the usual procedures.

Computing Lab

The main computing laboratory is room G012 of the Anita B.Lawrence Centre (formerly Red Centre). You can get to this lab by entering the building through the main entrance to the School of Mathematics (on the Mezzanine Level) and then going down the stairs to the Ground Level. A second smaller lab is Room M020, located on the mezzanine level through the glass door (and along the corridor) opposite the School's entrance.

For more information, including opening hours, see the computing facilities webpage. Remember that there will always be unscheduled periods when the computers are not working because of equipment problems and that this is not a valid excuse for not completing assessments on time.

School Contact Information

Please visit the School of Mathematics and Statistics website for a range of information.

For information on Courses, please go to “Student life & resources” and either Undergraduate and/or Postgraduate and respective "Undergraduate courses" and "Postgraduate courses" for information on all course offerings.

All school policies, forms and help for students can be located by going to the "Student Services" within “Student life & resources” page. We also post notices in "Student noticeboard" for your information. Please familiarise yourself with the information found in these locations. If you cannot find the answer to your queries on the web you are welcome to contact the Student Services Office directly.

Undergraduate

E: ug.mathsstats@unsw.edu.au

P: 9385 7011 or 9385 7053

Postgraduate

E: pg.mathsstats@unsw.edu.au

P: 9385 7053

Should we need to contact you, we will use your official UNSW email address of in the first instance. **It is your responsibility to regularly check your university email account. Please use your UNSW student email and state your student number in all emails to us.**