UNSW Course Outline

COMP9418 Advanced Topics in Statistical Machine Learning - 2024

Published on the 27 May 2024

General Course Information

Course Code : COMP9418
Year : 2024
Term : Term 2
Teaching Period : T2
Is a multi-term course? : No
Faculty : Faculty of Engineering
Academic Unit : School of Computer Science and Engineering
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Undergraduate, Postgraduate
Units of Credit : 6

Useful Links
Handbook Class Timetable

Course Details & Outcomes

Course Description

This course presents an in-depth study of statistical machine learning approaches. It aims to provide the student with a solid understanding of methods for learning and inference in structured probabilistic models, with a healthy balance of theory and practice. It will cover topics on the semantics of direct and undirected representations in probabilistic graphical models, exact and approximate inference, and learning of model parameters and structure.

In this course, we will study a class of statistical inference models known as Probabilistic Graphical Models (PGMs). PGMs are a great example of how Computer Science and Statistics can work together. PGMs use graph data structures to represent domains with large amounts of variables and specialised algorithms for efficient inference over these graphical models. Therefore, PGMs have pushed the limits of probability theory to the scale and rate necessary to provide automated reasoning in modern AI systems.

During this course, we will cover several graphical models, including Bayesian networks, Markov networks, Conditional Random Fields, Markov chains, Hidden Markov Models, Kalman Filters and Markov decision processes. We will have a clear understanding of how these models work as well as their main algorithms for inference and learning. We will also cover several algorithms used to learn parameters and make inferences such as Monte Carlo Markov Chains (MCMC), Gibbs Sampling, Viterbi and the Baum-Welch algorithms, among others.

Course Aims

Machine learning is at the intersection of Artificial Intelligence, Computer Science and Statistics. While the main goal of this course is to go beyond the basics of machine learning as provided by COMP9417 (focused on probabilistic modelling and inference), we will adopt a similar teaching rationale, where theory, algorithms and empirical analysis are all important components of the course. Therefore, the lectures, tutorials and assessments are designed to address these components jointly.

Relationship to Other Courses

This course relates more directly to the following courses:

- COMP9417 - Machine Learning and Data Mining
- COMP3411/COMP9414 - Artificial Intelligence and
- COMP4418 - Knowledge Representation and Reasoning

Similar to COMP9417, this course focuses on Machine Learning techniques. However, COMP9418 focuses more on models that use probabilities as the primary language for knowledge representation and reasoning. Machine Learning targets data-driven models, while the probabilistic models studied in COMP9418 are inherently interpretable and can be designed from experience, data, or a mixture of both.

COMP9418 shares similarities with other courses covering knowledge representation and reasoning, such as CPMP3411/COMP9414 and COMP4418. However, we focus on probabilistic models, while these courses have a broader view covering other representations, such as propositional and first-order logic and fuzzy sets. COMP9418 covers several probabilistic models, such as Bayesian and Markov Networks, Hidden Markov Models, Kalman Filters, and Conditional Random Fields, and demonstrates they are closely related to a common framework of probabilistic graphical models.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : Derive statistical independence assumptions from a given graphical representation of a probabilistic model
CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm
CLO3 : Derive and implement maximum likelihood learning approaches to latent variable probabilistic models
CLO4 : Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation
CLO5 : Understand and apply basic methods for structured prediction

Course Learning Outcomes	Assessment Item
CLO1 : Derive statistical independence assumptions from a given graphical representation of a probabilistic model	• Quizzes • Assignment 1 • Assignment 2 • Final Exam
CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm	• Quizzes • Assignment 1 • Assignment 2 • Final Exam
CLO3 : Derive and implement maximum likelihood learning approaches to latent variable probabilistic models	• Quizzes • Assignment 2 • Final Exam
CLO4 : Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation	• Quizzes • Assignment 2 • Final Exam
CLO5 : Understand and apply basic methods for structured prediction	• Final Exam

Learning and Teaching Technologies

Echo 360 | WebCMS

Learning and Teaching in this course

Machine learning is at the intersection of Artificial Intelligence, Computer Science and Statistics. While the main goal of this course is to go beyond the basics of machine learning as provided by COMP9417 (focused on probabilistic modelling and inference), we will adopt a similar teaching rationale, where theory, algorithms and empirical analysis are all important components of the course. Therefore, the lectures, tutorials and assessments are designed to address these components jointly.

The course involves lectures and practical work.

- *Lectures:* Aim to summarise the concepts and present case studies.
- *Tutorials:* Aim to reinforce the topics covered in lectures and will cover theoretical and practical exercises. The practical part of the tutorials will be based on a bring-your-own-device approach, where students will be introduced to the technology required for the assignments and follow a series of programming and data analysis questions. There will be no formal assessment of the tutorials.
- *Assignments:* Aim the same as the tutorials at a higher degree of difficulty and will be assessed.
- *Final exam:* Aim to assess the understanding of the course content and application in different use cases.

Engagement Tools and Blended Learning

- All lectures (slides/recordings) will be on the Web.
- All tutorial and lab materials (questions before, solutions after) will be on the Web.
- All assignments will have specifications on the Web and online submission.
- The final exam will likely be online.
- Forum for answering questions using WebCMS3.

Additional Course Information

In this course, we will study a class of statistical inference models known as Probabilistic Graphical Models (PGMs). PGMs are a great example of how Computer Science and Statistics can work together. PGMs use graph data structures to represent domains with large amounts of variables and specialised algorithms for efficient inference over these graphical models. Therefore, PGMs have pushed the limits of probability theory to the scale and rate necessary to provide automated reasoning in modern AI systems.

During this course, we will cover several graphical models, including Bayesian networks, Markov networks, Conditional Random Fields, Markov chains, Hidden Markov Models, Kalman Filters and Markov decision processes. We will have a clear understanding of how these models work as well as their main algorithms for inference and learning. We will also cover several algorithms used to learn parameters and make inferences such as Monte Carlo Markov Chains (MCMC), Gibbs Sampling, Viterbi and the Baum-Welch algorithms, among others.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Quizzes Assessment Format: Individual	10%	Start Date: Monday mornings for Weeks 2, 3, 4, 5, 7, 8, 9, and 10. Due Date: Sunday 6 pm for Weeks, 2, 3, 4, 5, 7, 8, 9, and 10.
Assignment 1 Assessment Format: Individual	15%	Start Date: 11/06/2024 12:00 PM Due Date: 30/06/2024 06:00 PM
Assignment 2 Assessment Format: Individual	15%	Start Date: 08/07/2024 12:00 PM Due Date: 04/08/2024 06:00 PM
Final Exam Assessment Format: Individual	60%	Start Date: To be scheduled Due Date: To be scheduled

Assessment Details

Quizzes

Assessment Overview

There will be eight weekly "take-home" quizzes during the term to act as both a mechanism for students to check their understanding of the material and as a small assessment item. Each quiz is composed of five multiple-choice questions. Marks are released to students weekly after the quiz's due date. The final mark for quizzes is the average of the eight quiz marks. Each quiz mark is normalised in the range of 0-10.

Course Learning Outcomes

- CLO1 : Derive statistical independence assumptions from a given graphical representation of a probabilistic model
- CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm
- CLO3 : Derive and implement maximum likelihood learning approaches to latent variable

probabilistic models
- CLO4 : Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation

Assessment Length

5 multiple-choice questions.

Submission notes

Submission through WebCMS or give.

Assignment submission Turnitin type

This is not a Turnitin assignment

Assignment 1

Assessment Overview

The assessment consists of implementing a set of programming questions and writing a 500-word report. Work will be marked against assessment criteria. The assessment criteria and solution, including test cases for programming questions, will be provided after the assessment due date. Written feedback per group is provided online.

Course Learning Outcomes

- CLO1 : Derive statistical independence assumptions from a given graphical representation of a probabilistic model
- CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm

Submission notes

Submission through WebCMS or give.

Assignment submission Turnitin type

This is not a Turnitin assignment

Assignment 2

Assessment Overview

The assignment involves designing and implementing a graphical model to solve a practical problem and writing a 2000-word report. Work will be marked against assessment criteria. Written feedback for each group will be provided online.

Course Learning Outcomes

- CLO1 : Derive statistical independence assumptions from a given graphical representation of

a probabilistic model
- CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm
- CLO3 : Derive and implement maximum likelihood learning approaches to latent variable probabilistic models
- CLO4 : Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation

Submission notes

Submission through WebCMS or give.

Assignment submission Turnitin type

This is not a Turnitin assignment

Final Exam

Assessment Overview

The exam will be open-book and take-home. Students are expected to complete the exam in 3 hours. Exams will be marked against assessment criteria. The assessment criteria and exam solution, including test cases for programming questions, will be published after the exam.

There is a hurdle on the Final Exam; very poor performance in the exam will result in a fail, even if all your other assessment marks have been satisfactory. The following formula describes how the mark will be computed and how the hurdle will be enforced.

quizzes = mark for quizzes (out of 10) ass1 = mark for assignment 1 (out of 15) ass2 = mark for assignment 2 (out of 15) exam = mark for exam (out of 60) okExam = finalExam >= 24/60 mark = quizzes + ass1 + ass2 + exam grade = HD|DN|CR|PS if mark >= 50 && okExam = FL if mark < 50 = UF if mark >= 50 && !okExam

Course Learning Outcomes

- CLO1 : Derive statistical independence assumptions from a given graphical representation of a probabilistic model
- CLO2 : Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm
- CLO3 : Derive and implement maximum likelihood learning approaches to latent variable probabilistic models
- CLO4 : Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation
- CLO5 : Understand and apply basic methods for structured prediction

Assessment Length

3 hours

Submission notes

Submit through WebCMS or give.

Assignment submission Turnitin type

This is not a Turnitin assignment

Hurdle rules

There is a hurdle on the Final Exam; very poor performance in the exam will result in a fail, even if all your other assessment marks have been satisfactory. The assessment overview section explains how the hurdle in enforced.

General Assessment Information

The following formula describes how the mark will be computed and how the hurdle will be enforced:

- quizzes = mark for quizzes (out of 10)
- ass1 = mark for assignment 1 (out of 15)
- ass2 = mark for assignment 2 (out of 15)
- exam = mark for exam (out of 60)
- okExam = exam >= 24/60
- mark = quizzes + ass1 + ass2 + exam
- grade = HD | DN | CR | PS if mark >= 50 && okExam
- grade = FL if mark < 50
- grade = UF if mark >= 50 && !okExam

Grading Basis

Standard

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 27 May - 2 June	Lecture	Course overview [Ch. 1], propositional logic [Ch. 2] and probability calculus [Ch. 3].
	Tut-Lab	Graph representation, traversal and other graph algorithms.
Week 2 : 3 June - 9 June	Lecture	Bayesian networks representation and semantics [Chs. 4 and 5].
	Tut-Lab	Probability calculus and factor implementation.
	Assessment	Quiz 1 is due.
Week 3 : 10 June - 16 June	Lecture	Exact inference [Ch. 6]. Bayesian networks as classifiers.
	Tut-Lab	Bayesian networks.
	Assessment	Assignment 1 description released.
	Assessment	Quiz 2 is due.
Week 4 : 17 June - 23 June	Lecture	Markov chains and hidden Markov models.
	Tut-Lab	Variable elimination.
	Assessment	Quiz 3 is due.
Week 5 : 24 June - 30 June	Lecture	MAP inference [Ch. 10]. Markov networks.
	Tut-Lab	Markov chains and hidden Markov models.
	Assessment	Assignment 1 due.
	Assessment	Quiz 4 is due.
Week 6 : 1 July - 7 July	Other	Flexibility Week.
Week 7 : 8 July - 14 July	Lecture	The jointree algorithm [Chs. 7 and 9].
	Tut-Lab	Markov networks.
	Assessment	Assignment 2 description released.
	Assessment	Quiz 5 is due.
Week 8 : 15 July - 21 July	Lecture	Gaussian Bayesian Networks [Koller Ch. 7, 14.1 & 14.2].
	Tut-Lab	Factor elimination and jointrees.
	Assessment	Quiz 8 is due.
Week 9 : 22 July - 28 July	Lecture	Belief propagation [Ch. 14]. Approximate inference by Sampling [Ch. 15].
	Tut-Lab	Gaussian Bayesian networks.
	Assessment	Quiz 7 is due.
Week 10 : 29 July - 4 August	Lecture	Learning parameters and graph structure [Ch. 17].
	Tut-Lab	Belief propagation and sampling.
	Assessment	Assignment 2 due.
	Assessment	Quiz 8 is due.

Attendance Requirements

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

General Schedule Information

Please note this is a tentative schedule. All dates are only indicative and subject to change.

We will post new content to WebCMS every Monday morning (before the lecture starts). We will email all students on Monday mornings, informing them of the new content and due dates for the week.

For every week in which an assessment item is due (quiz or assignment), the due date is Sunday at 6 p.m.

Course Resources

Prescribed Resources

Prescribed Book

- [Book] Modeling and Reasoning with Bayesian Networks. Adnan Darwiche. Cambridge. 2009 [eBook] [Print].

Recommended Resources

Recommended Books

- [Book] Probabilistic Graphical Models: Principles and Techniques. Daphne Koller and Nir Friedman. MIT Press. 2009 [Print].
- [Book] Probabilistic Graphical Models: Principles and Applications. Luis Enrique Sucar. Springer. 2015.
- [Book] Bayesian Reasoning and Machine Learning. David Barber. Cambridge University Press. 2012.
- [Book] Machine Learning: A Probabilistic Perspective. Kevin P. Murphy. MIT Press. 2012.
- [Book] Pattern recognition and machine learning. Christopher M. Bishop. Springer, 2006.

Course Evaluation and Development

This course is evaluated using the myExperience system.

In the previous offering of this course, students suggested some changes in the content sequence and the addition of new material covering continuous distributions. In conversation with the students, we also noted that the tutorial code needed to be faster to support their assessment implementations.

Based on their comments, we have placed the MAP lecture earlier in the course and reduced its content to allow space for a new lecture covering Gaussian Bayesian networks. We reimplemented the tutorial code, replacing an unordered dictionary with a NumPy array to increase code efficiency. We also improved code organisation using an object-oriented implementation.

We thank all the students who provided feedback on this course through MyExperience, email and conversations. These students include Martin Eftimoski, Gareth Dando, Lucky Zhan, Oliver Li and Darren Chong.

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Convenor	Gustavo Batista		J17, Room 510L		Tuesdays 5-6pm. Thursdays 3-4 pm.	Yes	Yes
Tutor	Yunrui Zhang					No	No
	Martin Eftimoski					No	No

Other Useful Information

Academic Information

I. Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to, or within 3 working days of, submitting an assessment or sitting an exam.

Please note that UNSW has a Fit to Sit rule, which means that if you sit an exam, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

II. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Equitable Learning Services

III. Equity and diversity

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course convener prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equitable Learning Services. Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

IV. Professional Outcomes and Program Design

Students are able to review the relevant professional outcomes and program designs for their streams by going to the following link: https://www.unsw.edu.au/engineering/student-life/student-resources/program-design.

Note: This course outline sets out the description of classes at the date the Course Outline is published. The nature of classes may change during the Term after the Course Outline is published. Moodle or your primary learning management system (LMS) should be consulted for the up-to-date class descriptions. If there is any inconsistency in the description of activities between the University timetable and the Course Outline/Moodle/LMS, the description in the Course Outline/Moodle/LMS applies.

Academic Honesty and Plagarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis or contract cheating) even suspension from the university. The Student Misconduct Procedures are available here:

www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

Submission of Assessment Tasks

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of five percent (5%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day. This is for all assessments where a penalty applies.

Work submitted after five days (120 hours) will not be accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These will be clearly indicated in the course outline, and such assessments will receive a mark of zero if not completed by the specified date. Examples include:

- Weekly online tests or laboratory work worth a small proportion of the subject mark;
- Exams, peer feedback and team evaluation surveys;
- Online quizzes where answers are released to students on completion;
- Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date; and,
- Pass/Fail assessment tasks.

Faculty-specific Information

Engineering Student Support Services – The Nucleus - enrolment, progression checks, clash requests, course issues or program-related queries

Engineering Industrial Training – Industrial training questions

UNSW Study Abroad – study abroad student enquiries (for inbound students)

UNSW Exchange – student exchange enquiries (for inbound students)

UNSW Future Students – potential student enquiries e.g. admissions, fees, programs, credit transfer

Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

School Contact Information

CSE Help! - on the Ground Floor of K17

- For assistance with coursework assessments.

The Nucleus Student Hub - https://nucleus.unsw.edu.au/en/contact-us

- Course enrolment queries.

Grievance Officer - grievance-officer@cse.unsw.edu.au

- If the course convenor gives an inadequate response to a query or when the courses convenor does not respond to a query about assessment.

Student Reps - stureps@cse.unsw.edu.au

- If some aspect of a course needs urgent improvement. (e.g. Nobody responding to forum queries, cannot understand the lecturer)

You should **never** contact any of the following people directly:

- Vice Chancellor

- Pro-vice Chancellor Education (PVCE)

- Head of School

- CSE administrative staff

- CSE teaching support staff

They will simply bounce the email to one of the above, thereby creating an unnecessary level of indirection and a delay in the response.