Course Outline

Important Notice for T3-2021

In T3-2021, we will have a fully online course. All lectures will be offered online in the form of topic-based videos, which you can watch in your own time. Tutorials will be held in the timetabled time slots. We will have online tutorials through MS Teams.

We are following the lockdown developments in New South Wales. In the case the conditions change and the lockdown restrictions are lifted, we may propose a subset of tutorials to be offered face-to-face.

Assignments and quizzes will be done online as usual. The Final Exam will most likely be held online.

Course Timetable

Lectures

COMP9418/1UGA COMP9418/1PGA	Week 1-5,7-10	Pre-recorded lectures on Youtube and Echo360	Online (https://www.youtube.com/playlist?list=PLeXZ7imUZFj_Tfko3a7WlsErCSyEXpojt)	Gustavo Batista
COMP9418/1UGA COMP9418/1PGA	Week 1-5,7-10	Thu 12:00 - 13:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3a5c54f3e2babb4653aa1c965b69509adc%40thread.tacv2/1631165070707?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%228743857b-7371-4ec1-a399-d29d62d59792%22%7d)	Gustavo Batista and Jeremy Gillen

Tutorials

T12A	tue12a	Week 1-5,7-10	Tue 12:00 - 14:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ameeting_OGFiZjMwOGYtYjdlYS00YTVmLWJiNzktNTE0YTk2YWViZjJi%40thread.v2/0?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%228743857b-7371-4ec1-a399-d29d62d59792%22%7d)	Payal Bawa
T14A	tue14a	Week 1-5,7-10	Tue 14:00 - 16:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ameeting_OGFiZjMwOGYtYjdlYS00YTVmLWJiNzktNTE0YTk2YWViZjJi%40thread.v2/0?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%228743857b-7371-4ec1-a399-d29d62d59792%22%7d)	Payal Bawa
T14B	tue14b	Week 1-5,7-10	Tue 14:00 - 16:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ab6b367d0f59245bcb2c6f3ced6f65e32%40thread.tacv2/1631504430257?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%22f0a673cb-0b0d-44dc-b052-de655d35d381%22%7d)	Peng Yi
W11A	wed11a	Week 1-5,7-10	Wed 11:00 - 13:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ae28143adf79e4625b26355da38b743c8%40thread.tacv2/1631504506777?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%22f0a673cb-0b0d-44dc-b052-de655d35d381%22%7d)	Peng Yi
W14A	wed14a	Week 1-5,7-	Wed 14:00 -	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ameeting_OGFiZjMwOGYtYjdlYS00YTVmLWJiNzktNTE0YTk2YWViZjJi%40thread.v2/0?	Payal Bawa

		10	16:00	context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%228743857b-7371-4ec1-a399-d29d62d59792%22%7d)	
W14B	wed14b	Week 1-5,7-10	Wed 14:00 - 16:00	Online MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ab36787c75a3c4aa596463e824903de99%40thread.tacv2/1631504576317?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%22f0a673cb-0b0d-44dc-b052-de655d35d381%22%7d)	Peng Yi

Overview

In this course, we will study a class of 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 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.

Contents

- Course Details
- Course Summary
- Assumed Knowledge
- Student Learning Outcomes
- Teaching Strategies
- Teaching Rationale
- Student Conduct
- Assessment
- Course Schedule
- Resources for Students
- Course Evaluation and Development

Course Details

Course Code	COMP9418
Course Title	Advanced Topics in Statistical Machine Learning
Convenor	Gustavo Batista (/users/z3527242)
Admin	Jeremy Gillen (/users/z3527242)
Consultations	Mondays 14:00-15:00, MS Teams (https://teams.microsoft.com/l/meetup-join/19%3ameeting_ODQ4NDNlNWMtNDRlZC00ZTRiLTk2OTgtYjFjMWQxOTQyYjFm%40thread.v2/0?context=%7b%22Tid%22%3a%223ff6cfa4-e715-48db-b8e1-0867b9f9fba3%22%2c%22Oid%22%3a%228743857b-7371-4ec1-a399-d29d62d59792%22%7d)
Units of Credit	6
Course Website	http://cse.unsw.edu.au/~cs9418/21T3/ (http://cse.unsw.edu.au/~cs9418/21T3/)
Handbook Entry	http://www.handbook.unsw.edu.au/postgraduate/courses/current/COMP9418.html (http://www.handbook.unsw.edu.au/postgraduate/courses/current/COMP9418.html)
Student Reps	stureps@cse.unsw.edu.au Email the stureps if you have any issues with the course. They will pass these anonymously to the relevant people to get the issues resolved.

Course Summary

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.

Assumed Knowledge

Official Pre-requisites

Knowledge of machine learning at the level of COMP9417.

Programming

We will use Python in the practical part of our bring-your-own-device tutorials. Students will have to install Jupyter Notebook on their computers to execute the practical part of the tutorials. Alternatively, they can remotely access the VLAB computers using a VPN (if outside UNSW) and software such as TigerVNC (https://tigervnc.org/) . However, it is expected that students unfamiliar with Python can get up to speed if they are able to construct (i.e., design, implement and test) working software in a general-purpose language such as C/C++ or Java, at least to the level of a first-year computing course (e.g., COMP1927 Computing 2 or equivalent). Having a good working knowledge of and be able to construct working software in standard data analysis languages such as Matlab/Octave, or R can also be helpful.

Software Tools

Since an important part of practical machine learning is "data wrangling" (i.e. pre-processing, filtering, cleaning, etc.) of data files, students are expected to master Unix tools such as those taught in COMP2041 Software Construction, or equivalents such as those in Matlab/Octave or R.

Student Learning Outcomes

After completing this course, students will:

1. Derive statistical independence assumptions from a given graphical representation of a probabilistic model
2. Understand and implement exact inference methods in graphical models including variable elimination and the junction tree algorithm
3. Derive and implement maximum likelihood learning approaches to latent variable probabilistic models
4. Understand and implement approximate inference algorithms in graphical models, including sampling and loopy belief propagation.
5. Understand and apply basic methods for structured prediction

This course contributes to the development of the following graduate capabilities:

Graduate Capability	**Acquired in**
Scholars capable of independent and collaborative enquiry, rigorous in their analysis, critique and reflection, and able to innovate by applying their knowledge and skills to the solution of novel as well as routine problems	Lectures, tutorials, assignments and exam
Entrepreneurial leaders capable of initiating and embracing innovation and change, as well as engaging and enabling others to contribute to change	Assignments
Professionals capable of ethical, self-directed practice and independent lifelong learning	Lectures, tutorials and assignments
Global citizens who are culturally adept and capable of respecting diversity and acting in a socially just and responsible way	Lectures, tutorials, assignments and student interactions

Teaching Strategies

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:* There will be a final exam.

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 (https://webcms3.cse.unsw.edu.au/COMP9418/20T3/forums/course) for answering questions using WebCMS3

Student Conduct

The **Student Code of Conduct** (Information (https://student.unsw.edu.au/conduct) , Policy (https://www.gs.unsw.edu.au/policy/documents/studentcodepolicy.pdf)) sets out what the University expects from students as members of the UNSW community. As well as the learning, teaching and research environment, the University aims to provide an environment

that enables students to achieve their full potential and to provide an experience consistent with the University's values and guiding principles. A condition of enrolment is that students *inform themselves* of the University's rules and policies affecting them, and conduct themselves accordingly.

In particular, students have the responsibility to observe standards of equity and respect in dealing with every member of the University community. This applies to all activities on UNSW premises and all external activities related to study and research. This includes behaviour in person as well as behaviour on social media, for example Facebook groups set up for the purpose of discussing UNSW courses or course work. Behaviour that is considered in breach of the Student Code Policy as discriminatory, sexually inappropriate, bullying, harassing, invading another's privacy or causing any person to fear for their personal safety is serious misconduct and can lead to severe penalties, including suspension or exclusion from UNSW.

If you have any concerns, you may raise them with your lecturer, or approach the School Ethics Officer (mailto:ethics-officer@cse.unsw.edu.au) , Grievance Officer (mailto:grievance-officer@cse.unsw.edu.au) , or one of the student representatives.

Plagiarism is defined as (https://student.unsw.edu.au/plagiarism) using the words or ideas of others and presenting them as your own. UNSW and CSE treat plagiarism as academic misconduct, which means that it carries penalties as severe as being excluded from further study at UNSW. There are several on-line sources to help you understand what plagiarism is and how it is dealt with at UNSW:

- Plagiarism and Academic Integrity (https://student.unsw.edu.au/plagiarism)
- UNSW Plagiarism Procedure (https://www.gs.unsw.edu.au/policy/documents/plagiarismprocedure.pdf)

Make sure that you read and understand this. Ignorance is not accepted as an excuse for plagiarism. In particular, you are also responsible that your assignment files are not accessible by anyone but you by setting the correct permissions in your CSE directory and code repository, if using. Note also that plagiarism includes paying or asking another person to do a piece of work for you and then submitting it as your own work.

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and 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.

If you haven't done so yet, please take the time to read the full text of

- UNSW's policy regarding academic honesty and plagiarism (https://student.unsw.edu.au/plagiarism)

The pages below describe the policies and procedures in more detail:

- Student Code Policy (https://www.gs.unsw.edu.au/policy/documents/studentcodepolicy.pdf)
- Student Misconduct Procedure (https://www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf)
- Plagiarism Policy Statement (https://www.gs.unsw.edu.au/policy/documents/plagiarismpolicy.pdf)
- Plagiarism Procedure (https://www.gs.unsw.edu.au/policy/documents/plagiarismprocedure.pdf)

You should also read the following page which describes your rights and responsibilities in the CSE context:

- Essential Advice for CSE Students (https://www.engineering.unsw.edu.au/computer-science-engineering/about-us/organisational-structure/student-services/policies/essential-advice-for-cse-students)

Please note due dates are subject to change.

Item	Topics	Due	Marks	Contributes to (learning outcomes)
Assignment 1	Weeks 1-2	Week 5	15%	1-2
Assignment 2	Weeks 3-7	Week 9	15%	3-4
Quizzes	Weeks 2-5,7-10	Weeks 2,3,4,5,7,8,9,10	10%	1-5
Final Exam	All topics	Exam period	60%	1-5

Quizzes are multiple-choice questions used to check the understanding during the course. The final mark for quizzes is the simple average of the eight quiz marks. Each quiz mark is normalised in the range 0-10.

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 precisely 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)
finalExam = finalExam (out of 60)
okExam    = finalExam >= 24/60
mark      = quizzes + labs + ass1 + ass2 + exam
grade     = HD|DN|CR|PS if mark >= 50 && okExam
          = FL if mark < 50
          = UF if mark >= 50 && !okExam
```

Course Schedule

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

Week	Lecture	Tutorial	Assignment	Quizzes
1	Course overview [Ch. 1], propositional logic [Ch. 2] and probability calculus [Ch. 3]	Graph representation, traversal and common algorithms	-	-
2	Bayesian networks representation and semantics [Chs. 4 and 5]	Probability calculus and factor implementation	-	Quiz 1
3	Exact inference [Ch. 6]. Bayesian networks as classifiers	Bayesian networks	Ass1 released	Quiz 2
4	Markov chains and hidden Markov models	Variable elimination	-	Quiz 3
5	MAP inference [Ch. 10]. Markov networks	Markov chains and hidden Markov models	Ass1 due	Quiz 4
6	Flexibility Week	-	-	-
7	Gaussian Bayesian Networks	Markov networks	Ass2 released	Quiz 5
8	The jointree algorithm [Chs. 7 and 9]	Gaussian Bayesian networks	-	Quiz 6
9	Belief propagation [Ch. 14]. Approximate inference by Sampling [Ch. 15]	Factor elimination and jointrees	Ass2 due	Quiz 7
10	Learning parameters and graph structure [Ch. 17]	Belief propagation and sampling	-	Quiz 8

Resources for Students

This website also has links to the auxiliary material/documentation that you will need for the course. Solutions for all tutorial questions and exercises will also be made available.

Prescribed Book

- [Book] Modeling and Reasoning with Bayesian Networks (https://www.cambridge.org/core/books/modeling-and-reasoning-with-bayesian-networks/8A3769B81540EA93B525C4C2700C9DE6) . Adnan Darwiche. Cambridge. 2009 [eBook (https://www.vitalsource.com/en-au/products/-v9781139637701)] [Print (https://www.bookshop.unsw.edu.au/details.cgi?ITEMNO=9780521884389)].

Recommended Books

- [Book] Probabilistic Graphical Models: Principles and Techniques (http://pgm.stanford.edu/) . Daphne Koller and Nir Friedman. MIT Press. 2009 [Print (https://www.bookshop.unsw.edu.au/details.cgi?ITEMNO=9780262013192)].
- [Book] Probabilistic Graphical Models: Principles and Applications (https://www.springer.com/gp/book/9781447166986) . Luis Enrique Sucar. Springer. 2015.
- [Book] Bayesian Reasoning and Machine Learning (http://web4.cs.ucl.ac.uk/staff/D.Barber/pmwiki/pmwiki.php?n=Brml.HomePage) . David Barber. Cambridge University Press. 2012.
- [Book] Machine Learning: A Probabilistic Perspective. (https://www.cs.ubc.ca/~murphyk/MLbook/) Kevin P. Murphy. MIT Press. 2012.
- [Book] Pattern recognition and machine learning (https://www.microsoft.com/en-us/research/people/cmbishop/#prml-book) . Christopher M. Bishop. Springer, 2006.

Other resources

- Stanford CS228 course notes (https://ermongroup.github.io/cs228-notes/)

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. We also reduced the content of this lecture 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 objected-oriented implementation.

We thank all the students that provided feedback to this course through MyExperience, email and conversations. These students include Martin Eftimoski, Gareth Dando, and many others.

Resource created 3 months ago (Thursday 19 August 2021, 11:18:04 AM), last modified 24 days ago (Wednesday 27 October 2021, 02:21:20 PM).

Comments (/COMP9418/21T3/forums/search?forum_choice=resource/64955) (/COMP9418/21T3/forums/resource/64955)

Christopher Gordon (/users/z5254857) about a month ago (Wed Oct 20 2021 21:00:42 GMT+1100 (AEDT))

Hi,
I was just wondering what textbook/chapter is associated with Hidden Markov Models and Markov Networks?

Jeremy Gillen (/users/z5118358) about a month ago (Thu Oct 21 2021 00:19:05 GMT+1100 (AEDT))

I just keyword searched the textbooks. For HMMs, I think references and short descriptions to them are spread out throughout Darwiche (like section 4.2), but it doesn't seem to have an in depth section. If you look in Koller & Friedman for "Temporal models", there is a section on representing them and a chapter on inference. It goes through a bunch of variations and extensions of HMMs.

For Markov Networks, see chapter 4 of Koller & Friedman. There's another chapter later on (20) that goes into detail of how the parameters are usually learned (bit different from the simple case in upcoming tutorial code).

Christopher Gordon (/users/z5254857) about a month ago (Thu Oct 21 2021 08:49:11 GMT+1100 (AEDT)), last modified about a month ago (Thu Oct 21 2021 08:49:32 GMT+1100 (AEDT))

Thank You

Guangwei Dong (/users/z5341535) 2 months ago (Mon Oct 04 2021 05:40:01 GMT+1100 (AEDT))

Hi,

I encounter an issue. I can not submit, because I forgot it's Summer Time in Australia now. May I submit it before 7pm?

Jeremy Gillen (/users/z5118358) 2 months ago (Mon Oct 04 2021 06:05:07 GMT+1100 (AEDT))

Yeah that is fair, I also forgot this morning. I extended this deadline to 9pm Sydney time. Remember the time for future quizzes though.

Guangwei Dong (/users/z5341535) 2 months ago (Mon Oct 04 2021 06:24:58 GMT+1100 (AEDT))

Thank you !!!