COMP2610/COMP6261 - Information Theory

Course Outline
Semester 2, 2022
(Last updated: July 18, 2022)

1 Course Information

1.1 Teaching Team

Professor Thushara Abhayapala
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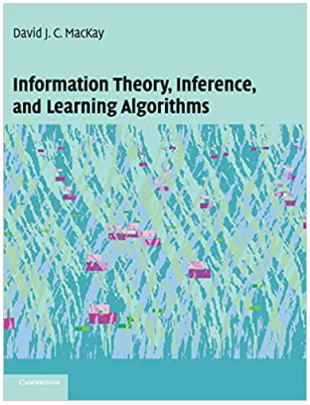
1.2 Pre-Requisite

There is no formal per-requisite (courses that you have to have completed), but you are expected to have a working familiarity with elementary probability theory. In particular, an understanding of **the notions of probability, conditional probability, expectation, other moments, distribution functions, density functions, joint distributions** and ability to perform simple calculations with these concepts are expected. The 'Teaching Team' will very quickly remind you of these concepts in the lectures. But we are not teaching them from scratch.

The self-administered Quiz we will make available in week 1 is designed to help you judge whether you have an adequate working knowledge to start following this course. ***If you do not have this necessary background, you will severely struggle in this course***. This statement is based on experience of seeing students in previous years who attempted this course without adequate background.

1.3 Recommended Text Book

David MacKay, "Information Theory, Inference, and Learning Algorithms", Cambridge University press, (primary text; available http://www.inference.org.uk/mackay/itila)



Additional reading:

- "Elements of Information Theory" by Cover and Thomas, 2nd Edition, New York, Wiley, 2006.
- "Pattern Recognition and Machine Learning," by Christopher M. Bishop

1.4 Web Site

https://wattle.anu.edu.au/
It is your responsibility to check the webpage **everyday** for course information and announcements.

1.5 Teaching and Learning Activities

1.5.1 Mode of Delivery

Lectures: Mostly On-campus and online (Dual Delivery). Some pre-recorded lectures will be provided as well as good, publicly available videos (e.g., from Youtube). Our goal is you to learn and for us to guide you.

Tutorials: There are 4 on-campus tutorial and one online (only) tutorial session on each week. Online Tutorial is reserved for remote students. Please use ANU MyTimeTable to enrol. Please note that on-campus tutes are not available online as it is difficult to have engaging participation in a mix mode. Online Tutorial will be run with the same interactive way but all participants are online.

		Day	Time	Location
Lectures:	Lecture 1	Tuesday	12 noon-1:00PM	Geography Bldg 48A SRES Theatre Rm 1.23
Weeks 1-12	Lecture 2	Wednesday	12 noon-1:00PM	Hedley Bull Bldg 130 Theatre 1
Tutorials:	Group A	Tuesday	9:00AM -10:00AM	Birch Bldg 35 Lab 1.35
	Group B	Tuesday	2:00PM - 3:00PM	Online Live only
(Weeks 1-12)	Group C	Wednesday	10:00AM - 11:00APM	Birch Bldg 35 Lab 1.29
	Group D	Thursday	2:00PM - 3:00PM	Birch Bldg 35 Lab 1.09
	Group E	Friday	2:00PM - 3:00PM	Birch Bldg 35 Lab 1.35

- These times have been set by ANU timetabling.
- Students are required to attend one tutorial every week. Tutorials are starting from the First week!

2 Course Description

2.1 Objectives

We live in an "information society" and build "information technologies". But what actually is information? Can one measure it? What are its properties? What are the limits of what one can do with it? For example, can one transmit information without error? Under what circumstances? What about compression of information? Why can one not compress a file twice over to make it smaller? And what about information in machine learning? What does

it mean to extract information from data? How much information can one extract. Finally, is information just one thing, or are there many different distinct notions of information? These questions are the motivation for the theory of information, or as it is usually known, "information theory."

2.2 Course Outline

This course provides an introduction to information theory, studying fundamental concepts such as probability, information, and entropy and examining their applications in the areas of data compression, coding, communications, pattern recognition and probabilistic inference.

Specific Topics:

1. Probability Theory, Bayes Rule and Bayesian Inference
2. Bayesian Inference and Entropy
3. Relative Entropy & Mutual Information
4. Fundamental and Probabilistic Inequalities, Law of Large Numbers, Typicality and Asymptotic Equipartition Property
5. Entropy, Coding, Compression - The Source Coding Theorem
6. Symbol Codes
7. Noisy Channels
8. Channel Capacity
9. Noisy Channel Coding Theorem

2.3 Desired Learning Outcomes

Upon successful completion of the course, the student will have background knowledge necessary to understand problems in data compression, storing and communication and undertake advanced courses on statistical inference, machine learning and information engineering. In particular, the student will be able to:

1. Understand and apply fundamental concepts in information theory such as probability, entropy, information content and their inter-relationships.
2. Understand the principles of data compression and be able to implement classical compression schemes by hand on toy problems.
3. Compute entropy and mutual information of random variables.
4. Implement and analyse basic coding and compression algorithms.
5. Understand the relationship of information theoretical principles and Bayesian inference in data modelling and pattern recognition.
6. Understand some key theorems and inequalities that quantify essential limitations on compression, communication and inference.
7. Know the basic concepts regarding communications over noisy channels.

2.4 Format of the course

- Two lectures per week. Tutorials starting week 1. In some weeks, we will only have one lecture. If we provide pre-recorded lectures, you are encouraged to watch them and attend the live lecture for a discussion. Tutorials are to provide assistance with your learning of the material. You will get way more out of them if you come prepared (having attempted the practice questions).

- You are at complete liberty to not attend any of the lectures or the tutorials. However, the Teaching Team think the lectures are useful, and we endeavour to make them interesting. **The subject is essentially mathematical and you simply cannot learn a mathematical subject without solving the problems yourself.** There is a monumental difference between attempting a problem yourself, and watching someone else do it. Mathematics is not a spectator sport. That is why we have tutorials, to help you with your attempt to solve the practice problems, not to passively watch others solve them. we say this explicitly because past experience suggests some students believe that they can master the material by merely watching. You can not. You are not obliged to attend the tutorials, but if you choose not to, you had better be very confident indeed in your ability to learn unaided.

- In principle you can just study the textbook and master the material by doing practice problems on your own. You are responsible for your learning. We are here to help you with your learning.

- We will make slides available before each lecture (typically only a day before). All lectures will be recorded and made available for download shortly after they are delivered. You should be aware that the lecture recording system has not proven to be 100% reliable, and thus we can not guarantee that all lectures will be successfully recorded.

3 Assessment

COMP2610 and COMP6261 share some assessment. You will have to do a different subset of questions in the assignments and the exam depending upon which course you are enrolled in.

There are FOUR components to the assessment for this course:

	Components	**Marks**
1.	Assignment 1	10%
2.	Assignment 2	20%
3.	Assignment 3	20%
4.	Final Exam	50% (**Hurdle component, min score required is 40% of the exam**)

3.1 Late Submission Policy

A late submission attracts a penalty of 5% per working day as per ANU Policy until a week from the due date. We will provide solutions to the assignment after a week from the due date and if you submit after that time you get zero marks (100% penalty).

Extensions will be considered according to the ANU Policy.

4 Tentative Course Schedule

More details about the lectures will be populated during the Semester.

Week	**Topic**	**Mackay** Section	**Due Dates**	**Tutorials**
1 July 25-29	L01 Motivate the course and cover logistics L02 Review of probability theory	2.1, 2.2 Bishop 1.2.1		Tute 1 (Mitchell)
2 Aug 1-5	L03 Probability Theory and Bayes' Rule L04 Bayesian Inference	2.1, 2.2 2.3		Tute 2 (Akram)
3 Aug 8-12	L05 Probability Distributions and Methods of Inference L06 Entropy	2.4, 23.1, 23.2, 8.1 Bishop 2.1,2.2	Release Assignment 1	Tute 3 (Akram)
4 Aug 15-19	L07 Relative Entropy and Mutual Information L08 Some fundamental inequalities	2.5, Ch 8 Cover 2.3, 2.4, 2.5		Tute 4 (Mitchell)
5 Aug 22-26	L09 Probabilistic Inequalities - Markov inequality, Chebyshev inequality and the Law of Large Numbers L10 :Entropy and Coding	4.4, 4.5 Cover 3.1	Assignment 1 Due Friday 5 pm	Tute 5 (Mitchell)
6 Aug 29 - Sep 2	L11 Entropy and Coding (Cont.) L12 The Source Coding Theorem	4.2-4.5	Release Assignment 2	Tute 6 (Zhifeng)
Teaching Break	No Lectures. Catch-up and Do Assignment 2			
7 Sep 19-23	L13 Symbol Codes for Lossless Compression L14 Source Coding Theorem for Symbol Codes (Youtube) Using Information Theory concepts in Deep Neural Network			Tute 7 (Manish)
8 Sep 26- Sep 30	L15 Shannon-Fano-Elias and Interval Coding L16 Arithmetic Coding		Assignment 2 Due Monday 9 AM	Tute 8 (Zhefang)
9 Oct 3-7	Guest Lecture L17 Noisy Channels		Student Survey	Tute 9 (Manish)
10 Oct 10-14	L18 Channel Capacity L19 Block Codes and the Coding Theorem		Release Assignment 3	Tute 10 (Manish)
11 Oct 17-21	L20 Joint-Typicality and the Noisy-Channel Coding Theorem L21 Hamming Codes & Coding Review			Tute 11 (Akram)
12 Oct 24-28	Guest lecture (Tentative) L22 Review and Exam Preparation		Assignment 3 Due Friday 5pm	Tute 12 (Zhefang)
	Examination period - from the 3rd November			