Australian National University

COMP2550/COMP4450/COMP6445

Advanced Computing R&D Methods Semester 1/2022

Introduction

Convenor: Prof. Jochen Renz

Intelligent Systems, School of Computing

Welcome to our R&D Methods course!

- This course is now a lecture based course
- Previously, this used to be a project based course. The Programs and Courses entry of the course still reflects this, this is wrong
- The idea of this course is to give you an overview of important research methods **before** you start your main research project
- Small team-based research projects (3 students/team) will be part of the tutorials

Course Information

- Course Convenor: Prof. Jochen Renz (jochen.renz@anu.edu.au)
- Note: If you email me, please always include your course code in the subject!
  (E.g. COMP2550, COMP4450, or COMP6445)
- Website: https://wattlecourses.anu.edu.au
- All course material including lecture recordings will be available on this page.

Course Overview

- The content of the course is a selection of important topics that will be useful and interesting for you once you start with your research projects
- I have selected several experts on these topics to give you an expert insight
- Each lecturer will also provide you with further reading material on these topics

  => Reference for your future research projects

Course Structure

- The course is a mix of lectures and tutorials. A mix of theory and hands-on experience to set you up for having a great first research experience.
- Some lecture content you might already know from other courses, but this course has a specific research focus and should serve as a reference for your future research.

Lecturers

- Dr Jenny Davis (CASS, jennifer.davis@anu.edu.au)
- Dr Jooyoung Lee, School of Computing (jooyoung.lee@anu.edu.au)
- Prof. Stephen Gould, School of Computing (stephen.gould@anu.edu.au)

Lecturers (continued)

- A/Prof. Peter Hoefner, School of Computing (peter.hoefner@anu.edu.au)
- Robert Farquharson, School of Philosophy (robert.farquharson@anu.edu.au)
- Dr Douglas Robertson, Director Research Services, (douglas.robertson@anu.edu.au)

Live online lecture access

- In addition to echo360 recordings, we stream all lectures live via zoom.
- Lecture access: Meeting ID = 862 2968 2293, password = **468306**, Zoom Link:

  https://anu.zoom.us/j/86229682293?pwd=eGlCaXV1SW9TVGRjMno2cDZMSEY2UT09

  Tuesdays 10am-12pm (China: 7am-9am, India 4:30am-6:30am, sorry!)
- On April 3 daylight saving ends, then all times will be 1h later in China and India…

Lecture Schedule (Tuesdays 10am-12pm, Live via Zoom, tentative)

- **22 Feb**: Introduction (Renz)
- **1 Mar**: Literature Analysis (Renz)
- **8 Mar**: Qualitative Research Methods (Davis)
- **15 Mar**: Quantitative Research Methods (Lee)
- **22 Mar**: Machine Learning Methods (Gould)
- **29 Mar**: Theoretical Research Methods (Hoefner)

Lecture Schedule (continued)

- **5 Apr, 12 Apr**: Teaching Break
- **19 Apr:** Philosophy of Science (Farquharson)
- **26 Apr:** Ethics, IP & Copyright (Robertson)
- **3 May:** Report writing workshop
- **10 May:** Presentation workshop
- **17 May**: Lightning Talks 1 (YOU)
- **24 May**: Lightning Talks 2 (YOU)

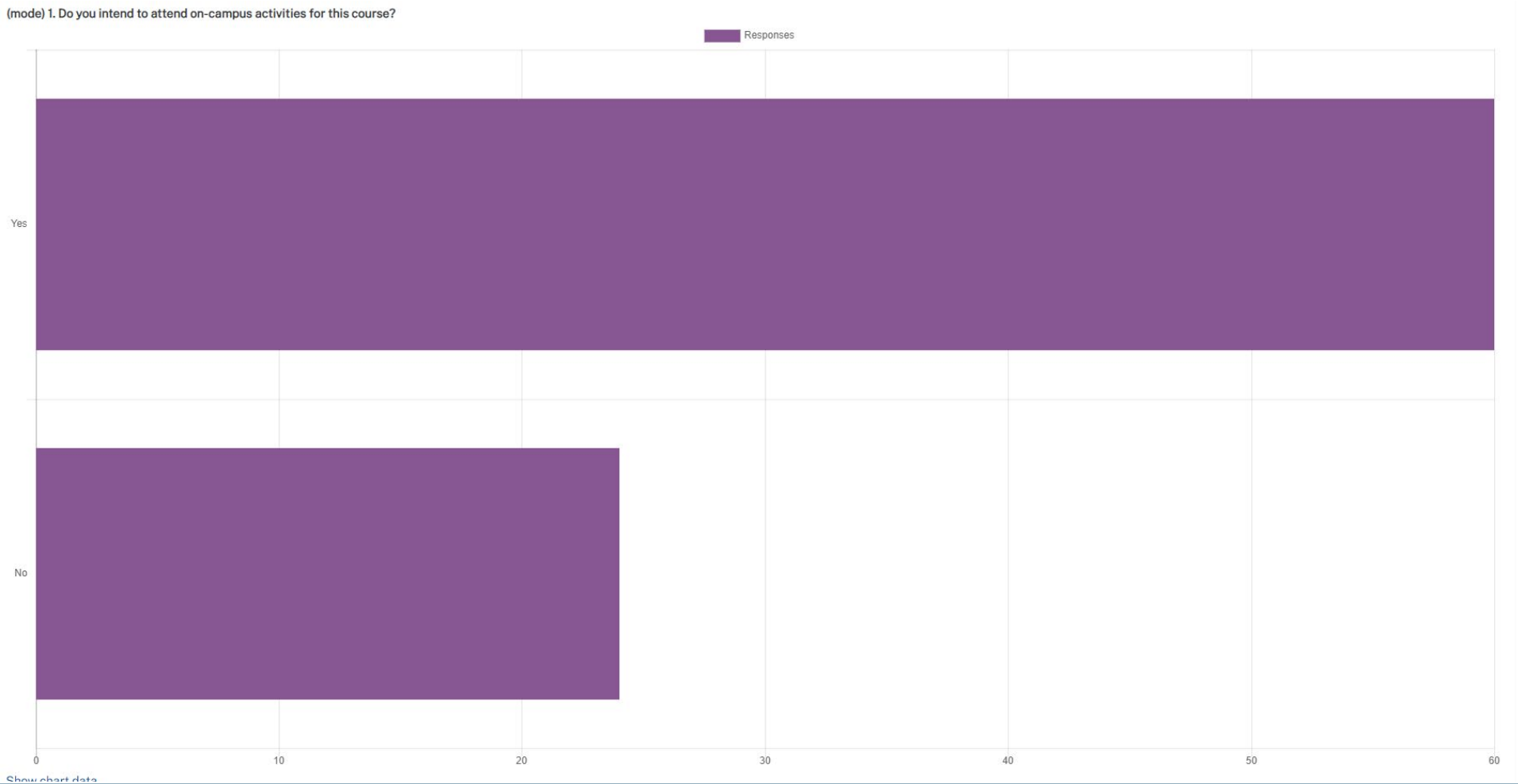
Weekly Tutorials (starting March 1)

- Each tutorial is dedicated to one research area selected by the tutor.
- We have 9 tutors **(=9 research areas**), at most 18 students can sign up per tutorial
- If enrolment numbers further increase, we will have additional tutorials (or go >18)
- You sign up for one tutorial on wattle, **first come first serve!**
- **Sign up opens on Thursday Feb 24, 4pm**

Online vs offline tutorials

- After previous experience, we decided to make all tutorials either online or offline
  - best possible experience for all students!
  - If in Canberra please sign up for an offline tutorial, if not, sign up for an online tutorial
- Probably ~3 online and ~6 offline tutorials
- Note: team research projects are part of the tutorials. Each team of 3 students must be part of the same tutorial.

Online or offline tutorial? Please complete the poll on Wattle by Feb 23!



What if you want to do a project with your friend overseas?

- You can join the same online tutorial as your overseas friend. But I do not recommend this! Some good reasons:
  - Pick a team based on joint research interests
  - It prepares you better for the future
  - If something goes wrong, you don't risk your friendship
  - Meet new people, make new friends
  - You are in the same time zone
  - You need 3 students per team anyway

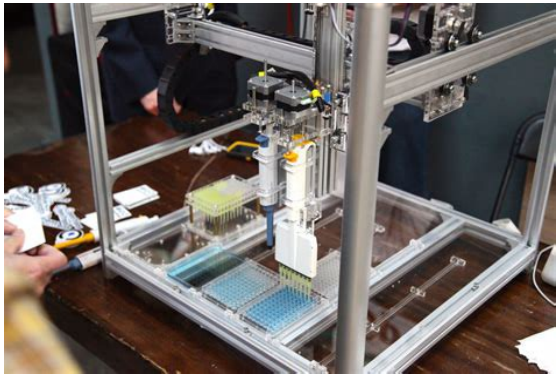
Your Tutors (1)

- Alexander Yang (Intuitive Physics + Physical Reasoning)
- Chathura Gamage (Procedural Content Generation in Games)
- Cheng Xue (Open-World learning, **Online!**)
- David Zhang (Software Testing for AI, **Online!**)

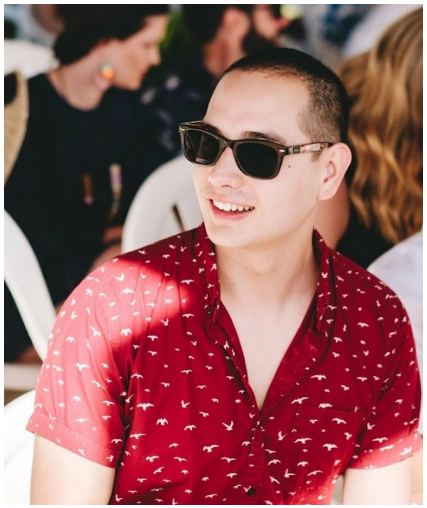
Your Tutors (2)

- Patrick Liston (Applied Approaches to Timeseries Analysis)
- Shidi Li (3D Computer Vision)
- Tommy Liu (Outlier Detection Methods)
- V Vijendran (Quantum Algorithms and Quantum Machine Learning)
- Vimukthini Pinto (AI Evaluation)

Intuitive Physics + Physical Reasoning



How can robots make the jump from controlled lab environments to the messiness of the real world?



Alexander Yang
PhD Candidate,
School of Computing

- Traditional physics: too brittle and rigid.
- Fuzzy **intuitive** physics: **reason** about likely outcomes with new objects and scenarios
- What are the building blocks of physical reasoning?
- How can they be engineered and evaluated?
- Perhaps by playing *Angry Birds*!
- Emerging approaches include:
  - Deep Reinforcement Learning,
  - Graph Neural Networks,
  - Self-Supervised Learning,
  - Neurosymbolic methods.

Prior Knowledge: basic familiarity with at least one area of AI will be a big advantage. Physics background ***not*** required.

Tutorial Research Topic

Procedural Content Generation In Games

- Have you ever been disappointed by your favourite game not having more levels to play, characters to meet, and areas to explore?
- This disappointment would no longer exist if we had a tool to generate game content at the rate it is being consumed.
- Procedural Content Generation (PCG) in Games is a research area that focuses on developing techniques to generate game content automatically which can be used to address the above concerns.
- PCG is used to generate game levels, maps, quests, characters, weapons, and sometimes complete games themselves.
- PCG also facilitates developing player adaptive games, creating endless games, and generating game content for game-playing AI.
- In this tutorial, we will discuss PCG in-depth including the state-of-the-art techniques that are used in different game genres.
- You will also get the chance to engage in your own team project that is interesting to you related to PCG.
- **Prerequisites**: No hard prerequisites. Knowledge in game development will be an added advantage.

Chathura Gamage
PhD Candidate
School of Computing

Realistic looking tree models generated using PCG
Image Credits: Wikipedia

Cheng Xue
PhD Candidate,
School of Computing
Research Interests:
Physical Reasoning
Open-world Learning
Neurosymbolic AI

Tutorial Research Topic:

Open-world Learning (Online!)

What is open-world learning?

- An open-learning framework has been defined as one that can 'deal with both normal in-distribution inputs and undesired out-of-distribution (OOD) inputs.'

Why open-world learning?

- Open-world learning has taken on new importance in recent years as AI systems continue to be applied and transitioned to real-world settings where unexpected events ('novelties') can, and do, occur.
- Designing AI that can operate in open worlds, including detecting, characterizing, and adapting to novelty, is a critical goal on the path to building intelligent systems that can work alongside humans to solve complex problems while being reliable enough to handle the unexpected.

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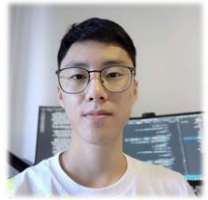
Software Testing for AI (Online!)

Tutorial Topic

AI software is different from traditional software, such that legacy software engineering practice may not be suitable for this new form of software. New testing methods are also needed to test AI. This tutorial will introduce SE4AI and AI4SE, with a particular focus on the testing for AI. We will explore software properties such as correctness, fairness, robustness, and look into how these properties and even testcases can be tested. You may come up with your own property definitions or testing method.

- Property definitions
- Test design
- Testcases generation
- Testing testcases



David Zhang
PhD Candidate
School of Computing
Software Systems @ CSIRO's Data61

Prerequisite

- There is no explicit prerequisite for this tutorial, but you should know some AI systems with basic understanding in order to find the appropriate testing methods.
- It will also help if you often notice the differences between things in daily life, such as figuring out the differences between PCR and RAT and how they result in different accuracies, or how apps work under different settings.

Tutorial Mode

- Online

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Software Testing for AI

Tutorial Topic

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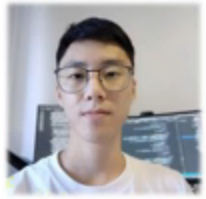

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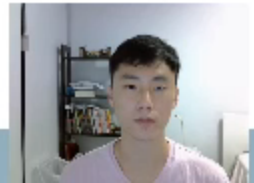
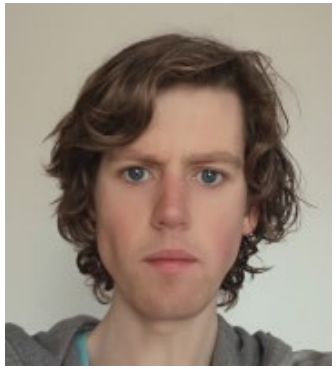


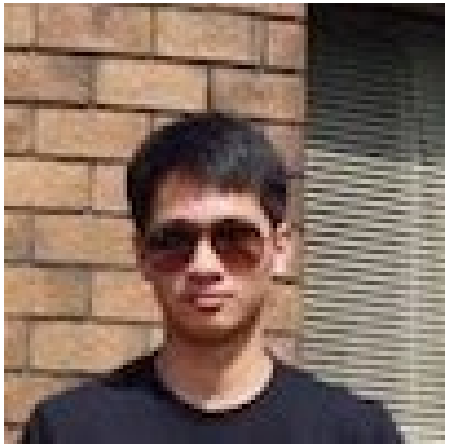
Applied Approaches to Timeseries Analysis

- Timeseries data has a wide range of uses. In our tutorials we will select from the areas suggested below and determine how and why we may use these methods in a meaningful way. We can apply the literature to practical problems (i.e using ML to spot ECG abnormalities) or look for gaps in the literature that we may address.

- Potential Areas
  - Continual Learning
  - Reinforcement Learning
  - Inverse Reinforcement Learning
  - Signal similarity measures
  - Transfer Learning
  - Applications in health data
  - Application in Financial markets / quant trading
- Prerequisites
  - Basic coding and mathematical skills



Patrick Liston
PhD Candidate,
School Of Computing



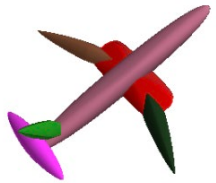
Shidi Li
PhD Candidate,
School of Engineering

Research Interests and Experience:

- Computer Vision,
- Deep Learning,
- Machine Learning

Tutorial Research Topics:
3D Computer Vision

- Representing 2D image is easy (a 2D matrix), but challenge in the 3D world due to time and memory complexity. Do you have ideas to describe 3D objects in real world?



- Build the 3D world: How to reconstruct 3D object from images? How to segment 3D object into meaningful parts? How to generate novel 3D objects?

Prerequisite:

- Basic knowledge of Deep learning theories.
- May requires access to a high-end GPU (and CUDA, Pytorch, Tensorflow…)
- May takes time learning 3D computer vision

Outlier Detection Methods

The definition of an outlier is not well defined and greatly varies depending on the goal of a researcher. Nonetheless, outliers play a significant role in the outcomes and conclusions of a study, and it is critical to have procedures to detect and deal with outliers.

Tutorial Goals:

- Determine how outlier detection plays a role in the modern data analysis and preprocessing contexts
- Define what an outlier is and how they can arise in the context of a given study.
- Quantify the impact(s) that outliers have upon a study and determine appropriate treatments to apply

Tommy Liu
PhD Candidate
Computational Sciences Group
Research Areas:

- Explainable AI+ML
- Data Preprocessing

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Quantum Algorithms & Quantum Machine Learning

Research Interests

My research is primarily on Quantum Algorithms and Quantum Information Science. I explore the interplay of physics, computer science and math to study the role of quantum mechanics in computation and information processing.

V Vijendran (Vijey)

4th-Year BAC(Hons) & BSC

Researcher at CQC2T

Topic Details

- There is a growing interest in finding useful applications of near-term quantum computers that are limited by noise and decoherence.
- Hybrid Quantum-Classical algorithms have been proposed to make the best of available quantum resources and integrate them with classical routines.
- We will look into how these Quantum-Classical algorithms may be used to solve NP and APX-Hard problems, and Machine Learning tasks.

Prerequisite: Interests in computation models, algorithms, and mathematics! + Comfortable reading rigorous proofs! *You'll have a head start if you have worked with any kind of optimisation problems.

Tutorial Research Topic: AI Evaluation

- If you are a commercial buyer for an AI product, how do you compare the products? How do you determine the advantages and disadvantages of a system and find which one suits you the best?
- Many years have been devoted toward the advancement of various aspects of artificial intelligence. However, one fundamental problem in AI is that nobody knows what intelligence is.
- AI evaluation is a field in AI that focuses on finding a true measure of intelligence that enables us to compare different intelligent solutions.
- In this tutorial, we discuss past attempts taken in developing a universal measure of intelligence, performance evaluation metrics for intelligent systems, and benchmark datasets developed for different areas of AI.

- **Topics you can propose**: Any topic related to AI evaluation that interests you. The topics may range from developing a theoretical measure of intelligence to developing a benchmark to solve a new problem in AI.
- **Prerequisites**: No hard prerequisites required.

Vimukthini Pinto

PhD Candidate
School of Computing

"Innumerable tests are available for measuring intelligence, yet no one is quite certain of what intelligence is, or even just what it is that the available tests are measuring."

R. L. Gregory (1998)

Weekly Tutorials (1. Selection phase, 5 weeks, March 1-April 1)

- First tutorial: detailed introduction to the topic
- Each tutorial is dedicated to the weekly lecture topic:
  - Every week the tutor hands out 2-3 published research papers on the intersection of the tutorial topic and the following weeks lecture topic
  - You must read these papers before the next tutorial and then discuss them in the tutorial
  - Reading papers is a big part of research!

Weekly Tutorials (1. Selection phase, 5 weeks, March 1-April 2)

- Part 1: You recap the lecture material and discuss the papers you read
- Part 2 (Brain storming): You discuss what other research questions and research problems fit into the intersection of tutorial and lecture topic and would be interesting to solve/answer and how.
- If you like a particular research question, you propose it as your research project. If 2 other students want to join you, you have a team!

- You must agree on a team/topic by April 1!!!

- **Inform the tutor about team and topic by April 1. Tutor must agree on the topic**

Weekly Tutorials (2. Project phase, 4 weeks, April 19-May 13)

- Start working on your project once selected (make good use of the teaching break!)
  - You study the literature and do some research e.g. experiments, implementation, analysis, etc
  - You present your progress during the weekly tutorials and discuss it with others
    - 15-20 minutes reporting and discussion per project
    - This gives you ideas and guidance and helps you articulate your ideas and thoughts
    - Share ideas and criticism with others, you all benefit!

Weekly Tutorials (3. Presentation phase, 2 weeks, 1 tutorial, May 19-27)

- At the end of the course, each team gives a 15 minute talk in their tutorial
- Each team gives a 4 minute lightning talk during one of the lectures on May 17 & 24
  - **everyone needs to attend at least one of these two lectures (Mark your calendar!)**
- Each team also submits a report on their project including a literature survey

Lab Sessions (tbd, based on demand)

- Some of the tutorials come with an additional lab session where you can experiment with things you learned and tools and methods you were introduced to.
- Labs introduce you to software you might want to use as part of your projects.
- Not compulsory, only if you need them.
- I will announce these via wattle and ask how many of you want to attend.

Interactive Workshops

- We will have some interactive workshops to provide you with important additional skills:
  - Time Management and Teamwork (March 24, 11am-12pm)
  - Reading strategies, note taking and report writing (May 3, lecture slot)
  - Presenting your research (May 10, lecture slot)
- Workshops are online via zoom and recorded
- Note: Workshops are provided by Academic Skills and Learning Centre. They offer more workshops, please check their website if interested.

Assessment

- We will have a total of 5 assignments plus a tutorial mark, no exams.
- In order to pass the course, you need 50% of the total marks
- Complaints about marks within 2 weeks!

The Five Assignments

- #1. Tutorial topic (15%)
- #2. Paper review (15%)
- #3. Team project report (30%)
- #4. Team project presentation (15%)
- #5. Individual project proposal (15%)
- In addition: Tutorial mark for project updates and discussions (10%, 1% per tutorial)

Tentative Assignment Schedule

- Assignment 1 (15%): Out Mar 1 Due Mar 22
- Assignment 2 (15%): Out Mar 22 Due Apr 19
- Assignment 3 (30%): Out Mar 29 Due May 27
- Assignment 4 (15%): Out May 3 Due May 31
- Assignment 5 (15%): Out April 19 Due May 14*

All due at 11.59pm on due date. Late submission not allowed (only with approved extension: https://policies.anu.edu.au/ppl/document/ANUP_004604)

Assignment Marking Principle

- General marking rule: If there is nothing wrong with your assignment (spelling, content, structure, etc, you can get at most 80% of the total mark.
- If you want more than 80%, you need to demonstrate something exceptional, for example, excellent: creativity, presentation, discussion, motivation, results, analysis, use of techniques/methods, understanding, etc.

Teamwork Assignments (#3 and #4)

- #3: Each team member needs to do a component of the report. Statement of contribution needs to be included
- #4: Each team member needs to present a substantial part of the two talks (>=4 min)
- Teamwork is very important in research, here you will practice working together
- We will offer a workshop where we discuss about teamwork, do's, don't's etc.

Assignment #5 Project Proposal

- In this assignment you will have to write an individual research project proposal.
- Must be different from your team project
- I strongly encourage you take this opportunity to already select your next research project (e.g. COMP2560 or Honours project) and start preparing over the semester break!
- We could push deadline to exam period?

Tutorial Marks (10%)

- You are expected to contribute actively and constructively to the research discussions.
- Prepare for the tutorials, read the papers
- For each tutorial #1-#10, tutors assign marks depending on your individual contribution: 1 (excellent), 0.5 (standard), 0 (very little/none)
- Quality is more important than quantity
- If a team doesn't do progress report in phase 2, each team member gets 1 mark deducted.

Important Note

- If you have any serious concerns about the assessment scheme or about the assignment schedule, please let me know what you would like changed and how by Monday February 28.
- The assessment scheme needs to be locked in by Friday March 4 (=ANU requirement).

Plagiarism Policy (Important!)

- Any student is expected to be able to explain and defend any submitted assessment item. Convenor can conduct or initiate an additional interview about any submitted assessment item for any student.
- If there is a significant discrepancy between the two forms of assessment, it will be automatically treated as a case of suspected academic misconduct.
- Note: We will do some random interviews

Plagiarism Policy (Important!)

- If plagiarism is detected in one assignment, it will count as 0 marks, repeat = fail course.
- To avoid any suspicion of plagiarism: **always do all your assignments on your own (except #3/4 and cite all your sources!!!)**
- Every year some students plagiarise in this course and get caught. This is a very stressful experience for students and usually ends in tears: Be smart. Don't do it!

CECS Class Representatives

Class Student Representation is an important component of the teaching and learning quality assurance and quality improvement processes within the ANU College of Engineering and Computer Science (CECS).

The role of Student Representatives is to provide ongoing constructive feedback on behalf of the student cohort to Course Conveners and to Associate Directors (Education) for continuous improvements to the course.

Roles and responsibilities:

- Act as the official liaison between your peers and convener.
- Be creative, available and proactive in gathering feedback from your classmates.
- Attend regular meetings, and provide reports on course feedback to your course convener
- Close the feedback loop by reporting back to the class the outcomes of your meetings.

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– Why become a class representative?

- **Ensure students have a voice** to their course convener, lecturer, tutors, and College.
- **Develop skills sought by employers**, including interpersonal, dispute resolution, leadership and communication skills.
- **Become empowered**. Play an active role in determining the direction of your education.
- **Become more aware of issues influencing your University** and current issues in higher education.
- **Course design and delivery.** Help shape the delivery of your current courses as well as future improvements for following years.

- Note: Class representatives will need to be comfortable with their contact details being made available via Wattle to all students in the class.

- For more information regarding roles and responsibilities, contact:
- ANUSA CECS representatives: sa.cecs@anu.edu.au

Want to be a class representative? Nominate today!

We need three class representatives: COMP2550, COMP4450, COMP6445

Please nominate yourself to your course convener by 2nd March 2022.

You are free to nominate yourself whether you are currently on-campus or studying remotely.

Some general information

- The deadline for enrolling into courses via ISIS is February 28
- The deadline for dropping courses without picking a replacement course is March 31 (Census date)
- The deadline for dropping a course without failure (WD) is May 6.

Your feedback is very important

- Is there anything you would like covered in more detail, or covered at all? Any other suggestion how we can provide you with more useful information and skills?
- Any complaints or compliments?
- Please email me feedback or discuss in person (Hanna Neumann, 3rd floor).
- SELT survey will be available as well.

Search Engineering & Computer Science

GO

CURRENT STUDENTS

- Meet CECS Student Services
- Getting started »
- Frequently asked questions
- Opportunities and projects »
  - CECS 3MT
  - International study and experience
  - Previous opportunities
  - Professional development »
  - Scholarships and grants »
  - Humanitarian Engineering »
- Student research projects
- Support and wellbeing »
- Policies and resources »
- All current active opportunities
- COVID-19

RELATED SITES

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» Current students » Opportunities and Projects

Opportunities and Projects

International study and experience

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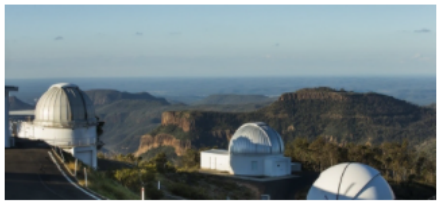
Support services

Humanitarian Engineering



Student projects

Thank You!

- I hope you will enjoy the course and find it useful and interesting.

- Any questions?

For reference: Course Description

The course introduces students to some fundamentals of research methodology. The course comprises a series of lectures which cover the following topics: Philosophy of Science, Quantitative Research Methods, Qualitative Research Methods, Basic Machine Learning Methods, Theoretical Research Methods, Literature Analysis, Reading and Reviewing Papers, Research Ethics and Commercializing Research.

The lectures will be complemented by a series of tutorials, labs and assignments that require students to do some small research focused tasks that help them get a hands-on experience of research, both individually and in teams of students. This includes different tasks such as topic modeling, statistical analysis, applying different machine learning techniques to solve a problem in a team, proving theorems, complexity analysis, designing a research project, reviewing papers and presenting papers.

Tutorials will give students the opportunity for intense research discussions on a topic of their choice, Students will conduct a small team-based research project, regularly discuss their progress with others and present their outcomes in class. At the end of the course, students will be confident to start working on their own research projects.