COMP9444: Neural Networks and Deep Learning

Week 1: Overview

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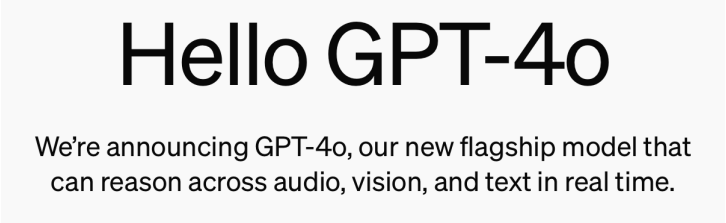
Recent AI breakthroughs



- You can get answers, find inspiration, and be more productive
- Summarise meetings. Find new insights. Increase productivity
- Generate and debug code. Automate repetitive tasks. Learn new APIs
- Create images
- ...

Source: https://openai.com/chatgpt/

Recent AI breakthroughs

AI now beats humans at basic tasks — new benchmarks are needed, says major report

Stanford University's 2024 AI Index charts the meteoric rise of artificial-intelligence tools.

A woman plays Go with an AI-powered robot developed by the firm SenseTime, based in Hong Kong. Credit: Joan Cros/NurPhoto via Getty

Recent AI breakthroughs

Millions of new materials discovered with deep learning

Source: https://deepmind.google/discover/blog/millions-of-new-materials-discovered-with-deep-learning/

Recent AI breakthroughs

World Economic Forum

EMERGING TECHNOLOGIES

‘AI will likely make drugs cheaper and more accessible for everybody on the planet’ – 3 technologists on AI and scientific discovery

Jul 5, 2024

Source: https://www.weforum.org/agenda/2024/07/technologists-ai-scientific-discovery/

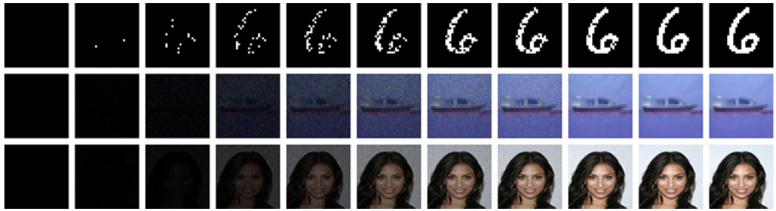
Recent AI breakthroughs

Generative AI

AI breakthrough creates images from nothing

Innovative framework that generates images from nothing can enable new scientific applications

JANUARY 12, 2024



A new generative AI model can create images from a blank frame.

SHARE

RELATED STOR

ChemCam fires it

Source: https://discover.lanl.gov/news/0111-ai-breakthrough/

Recent AI breakthroughs

HEALTH

Dementia Breakthrough: New AI Solves in Minutes a Challenge That Would Take Neuroscientists Weeks

BY UNIVERSITY OF COPENHAGEN - FACULTY OF SCIENCE — MAY 30, 2024 NO COMMENTS 5 MINS READ

Facebook Twitter Pinterest Telegram

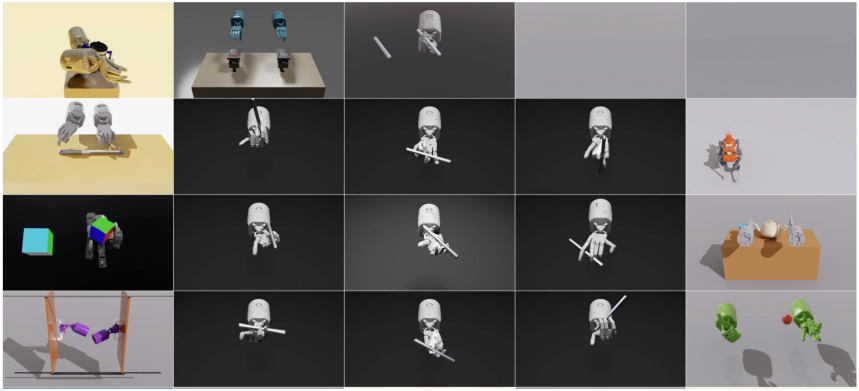
Researchers at the University of Copenhagen have developed a machine learning algorithm that allows for real-time

Recent AI breakthroughs

Eureka! NVIDIA Research Breakthrough Puts New Spin on Robot Learning

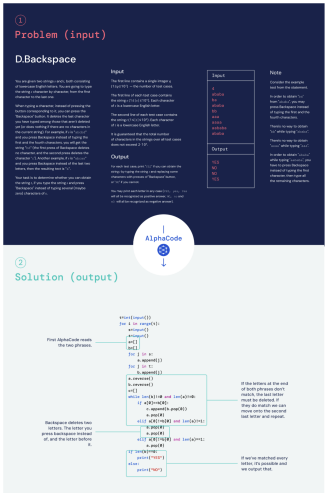
AI agent uses LLMs to automatically generate reward algorithms to train robots to accomplish complex tasks.

October 20, 2023 by Angie Lee



Source: https://blogs.nvidia.com/blog/eureka-robotics-research/

Recent AI breakthroughs



Source: https://deepmind.google/discover/blog/competitive-programming-with-alphacode/

Recent AI breakthroughs

Multimodal AI: Models that can understand different modalities (images, text, audio, etc.)

"man in black shirt is playing guitar."

"construction worker in orange safety vest is working on road."

"two young girls are playing with lego toy."

Source: https://cs.stanford.edu/people/karpathy/deepimagesent/

Recent AI breakthroughs

Multimodal AI: Models that can understand different modalities (images, text, audio, etc.)

Source: https://visualqa.org

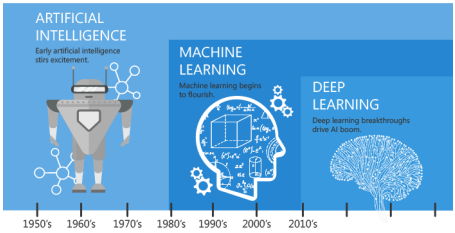
Recent AI breakthroughs

Multimodal AI: Visual grounding for referring expressions for Human-Robot Interaction

Source: https://drive.google.com/file/d/15AttCp-KCDEt8Ys5TfqXowsElm9GqAkH/view?pli=1

Artificial Intelligence, Machine Learning, and Deep Learning

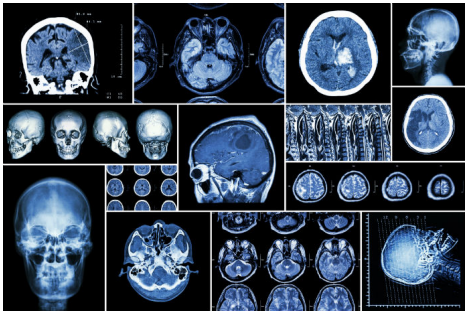
- **Artificial Intelligence**: development of smart systems and machines that can carry out tasks that typically require human intelligence
- **Machine Learning**: creates algorithms that can learn from data and make decisions based on patterns observed. Requires human intervention when decision is incorrect
- **Deep Learning**: uses complex and deep artificial neural networks to reach accurate conclusions without human intervention. Requires large-scale annotated data to train



Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

Why Deep Learning is getting better?

- Increasing availability of data: Electronic Health Records, Digitisation of processes
- Improvement in Computing Power: Rise of Graphics Processing Units (GPUs)
- Advances in algorithms: Better and robust neural networks, improved techniques to train networks
- **Deep Learning = Convergence of data, models, and computing power**



Course Web Pages

- **WebCMS**: https://webcms3.cse.unsw.edu.au/COMP9444/24T3/
- **Ed**: https://edstem.org/au/courses/18763/discussion/
- **Moodle**: https://moodle.telt.unsw.edu.au/course/view.php?id=86736

Lecturers, Course Admins

- **Lecturer-in-Charge**: Dr Sonit Singh
- **Lecturer**: Dr Alan Blair
- **Course Admin**: Zhongsui Guo
- **Email**: cs9444@cse.unsw.edu.au

Course Schedule

Lectures (Week 1 to Week 10)

- **Lecture A**: Tuesday; 9-11 am; Mathews Theatre (K-D23-Theatre A)
- **Lecture B**: Thursday; 11-1 pm; Mathews Theatre (K-D23-Theatre A)

Tutorials (Week 1 to Week 5)

- Check your respective tutorial on https://timetable.unsw.edu.au/2024/COMP9444.html#S3S

Project Mentoring Sessions (Week 7 to Week 10)

- More details in next slides

CSE Help Sessions (Optional, tentative)

Teaching Strategies

- Course materials will be delivered through the course Ed page — including text, images, online discussion forums, quizzes, and coding exercises.
- You are encouraged to read through the materials on Ed before each Lecture.
- Lecture time will be used to summarise the material, discuss recent developments, and answer questions.
- Tutorials in Week 1 to Week 5, to discuss worked examples and develop a deeper understanding of fundamental topics.
- Mentoring sessions (Week 7 to 10) to assist with Group Project.
- Help sessions will assist with any queries related to course content and to assist to assessments.

Teaching Strategies

You must keep up with lectures, either by attending in person or watching the recordings. Students enrolled in the Web stream are welcome to attend in person if space is available.

You are expected to:

- review course materials before and after each lecture.
- attempt tutorial questions beforehand and be ready to ask questions.
- complete quizzes, coding exercises, and relevant questions.
- discuss the material with your fellow students if possible.
- consider further exploring topics of particular interest.
- ask questions and contribute to discussion in online Ed forums.

Textbook(s)

The textbook for this course is:

Understanding Deep Learning
by Simon J.D. Prince
MIT Press, 2023
https://udlbook.github.io/udlbook/

Another good reference book is:

Deep Learning
by Ian Goodfellow, Yoshua Bengio and Aaron Courville
MIT Press, 2014
https://www.deeplearningbook.org/
https://mitpress.mit.edu/9780262035613/deep-learning/

Assumed Knowledge

The course will assume knowledge of the following mathematical topics:

- Linear Algebra (2.1-2.8)
- Probability (3.1-3.14)
- Calculus and Chain Rule (6.5.2)

You should study the relevant sections of the textbook (shown in brackets) and, if necessary, try to revise these topics on your own during the first two weeks of the course.

Planned Topics (Weeks 1-5)

- **Week 0**: Introduction to course, Python refresher, Numpy refresher, Matplotlib refresher, Google Colab refresher
- **Week 1**: Neuroanatomy and Perceptrons, Multi-layer perceptrons and Backpropagation
- **Week 2**: Probability, Generalisation & Overfitting, PyTorch
- **Week 3**: Cross Entropy, SoftMax, Weight decay, Momentum, Hidden Unit Dynamics
- **Week 4**: Convolutional Neural Networks, Image Processing
- **Week 5**: Recurrent Neural Networks (RNN), Long Short-Term Memory Network (LSTM), Gated Recurrent Unit (GRU)

Planned Topics (Weeks 6-10)

- **Week 6**: Flexibility Week
- **Week 7**: Word Vectors, Language Processing, Large Language Models (LLMs)
- **Week 8**: Reinforcement Learning, TD-learning and Q-learning, Policy Learning, Deep Reinforcement Learning
- **Week 9**: Autoencoders, Adversarial Training, Multimodal learning
- **Week 10**: Generative Artificial Intelligence (GenAI), Review (optional)

Assessments

Assessments will consist of:

- Assignment (individual): 17%
- Class Participation (individual + group-based): 8%
- Group Project (group-based): 30%
- Final Exam (in-person, invigilated): 45%

Due dates:

- Assignment 1: Due Week 5
- Group Project: Due Week 10
- Final Exam: UNSW Exam Period

Note: In order to pass the course, you must achieve a total mark of at least 50.
Note: Students are expected to form themselves into groups of 5 for the group project by the end of Week 4.

Assignment (individual)

The assignment may involve, for example:

- using code written in PyTorch
- writing your own code
- running experiments and analysing the results

Further details will be provided on the course website.

Class Participation (individual + group-based)

- Week 1 to Week 5: Individual
- Week 7 to Week 10: Group

Class Participation

Week	Tasks	Marks
Week 1	Tutorial Exercises; **Tensor Basics**	1 mark
Week 2	Tutorial Exercises; **PyTorch; Paper Reading**	1 mark
Week 3	Tutorial Exercises; **Paper Reading**	1 mark
Week 4	Tutorial Exercises; **Group Formation; Finalising Project; Finding Dataset(s); Project Planning**	1 mark
Week 5	Tutorial Exercises; **Literature Review; Dataset Analysis**	1 mark
Week 6	Flexible Week	
Week 7	**Implementing baseline method/model; Model training and evaluation; Results analysis; Ideas how existing solution(s) could be improved**	1 mark
Week 8	**Implement idea(s) to improve existing work OR do comparative analysis OR do novel data analysis**	1 mark
Week 9	**Discuss main findings of the proposed solution; Discuss strengths and weaknesses of the proposed solution; Do comparison to other methods(s); Draft recommendations for future work; Draft slides for the final project presentation**	1 mark
Week 10	**Final Project Presentation; Project Submission (including Notebook(s), Report, and Slides)**	

Group Project

The group project involve the following:

- forming teams (5 members) by the end of Week 4
- try to form a team from within the same tutorial. However, we do understand that you may want to form team from other tutorials. In later case, either members should be happy to move to different tutorial (change of day/time)
- team members can be a mix of undergraduates/postgraduates
- choose group based on the provided list
- an assigned mentor will guide you on the chosen project
- Discuss project progress with your mentor and seek help throughout the term
- Group need not be present for the entire 2 hour session
- Project evaluations in Week 10
- Deliverables: Source code (Jupyter Notebook), Presentation, Report

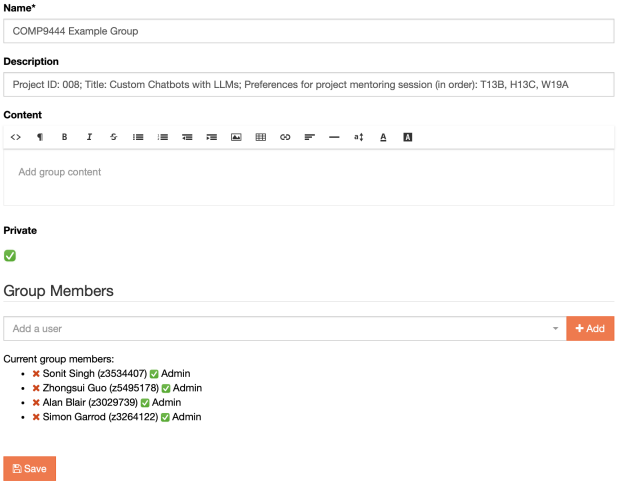
Group Formation (Slots available)

S.No.	Class Number	Tutorial Name	Day	Timing	Room
1	4330	F09A	Fri	09:00-11:00	Quadrangle 1042 (K-E15-1042)
2	4331	F09B	Fri	09:00-11:00	Quadrangle G042 (K-E15-G042)
3	13086	F10A	Fri	10:00-12:00	Goldstein G07 (K-D16-G07)
4	4332	F11A	Fri	11:00 - 13:00	Quadrangle 1042 (K-E15-1042)
5	4333	F11B	Fri	11:00 - 13:00	Quadrangle G042 (K-E15-G042)
6	13089	F12A	Fri	12:00-14:00	Electrical Engineering G04 (K-G17-G04)
7	4334	F13A	Fri	13:00 - 15:00	Online (ONLINE)
8	4335	F13B	Fri	13:00 - 15:00	Quadrangle G042 (K-E15-G042)
9	4336	F13C	Fri	13:00 - 15:00	Squarehouse 207 (K-E4-207)
10	4337	F15A	Fri	15:00 - 17:00	Quadrangle G042 (K-E15-G042)
11	4338	F15B	Fri	15:00 - 17:00	Quadrangle 1042 (K-E15-1042)
12	4339	F15C	Fri	15:00 - 17:00	Online (ONLINE)
13	4340	F17A	Fri	17:00 - 19:00	Quadrangle 1042 (K-E15-1042)
14	4341	H09A	Thu	09:00 - 11:00	Quadrangle 1042 (K-E15-1042)
15	4342	H09B	Thu	09:00 - 11:00	Quadrangle G042 (K-E15-G042)
16	4343	H13A	Thu	13:00 - 15:00	Quadrangle 1042 (K-E15-1042)
17	4344	H13B	Thu	13:00 - 15:00	Online (ONLINE)
18	4345	H13C	Thu	13:00 - 15:00	H13 Lawrence West 3037 (K-H13-3037)
19	4346	H13D	Thu	13:00 - 15:00	Squarehouse 208 (K-E4-208)
20	4347	H13E	Thu	13:00 - 15:00	Morven Brown LG30 (K-C20-LG30)
21	4348	H15A	Thu	15:00 - 17:00	Quadrangle 1042 (K-E15-1042)
22	4349	H15B	Thu	15:00 - 17:00	Goldstein G07 (K-D16-G07)
23	4350	H17A	Thu	17:00 - 19:00	Quadrangle 1042 (K-E15-1042)
24	4351	H19A	Thu	19:00 - 21:00	Quadrangle 1042 (K-E15-1042)
25	4352	T11A	Tue	11:00 - 13:00	Quadrangle G042 (K-E15-G042)
26	4353	T11B	Tue	11:00 - 13:00	Squarehouse 218 (K-E4-218)
27	4354	T12A	Tue	12:00 - 14:00	Library 176B (K-F21-176B)
28	4355	T12B	Tue	12:00 - 14:00	Library 176A (K-F21-176A)
29	4356	T13A	Tue	13:00 - 15:00	Squarehouse 207 (K-E4-207)
30	4357	T13B	Tue	13:00 - 15:00	Quadrangle 1001 (K-E15-1001)
31	4358	T15A	Tue	15:00 - 17:0	Squarehouse 218 (K-E4-218)
32	4359	T17A	Tue	17:00 - 19:00	Squarehouse 218 (K-E4-218)
33	4360	T19A	Tue	19:00 - 21:00	Library 176B (K-F21-176B)
34	4361	W09A	Wed	09:00 - 11:00	Quadrangle 1042 (K-E15-1042)
35	4362	W11A	Wed	11:00 - 13:00	Quadrangle 1042 (K-E15-1042)
36	4363	W13A	Wed	13:00 - 15:00	Online (ONLINE)
37	4364	W15A	Wed	15:00 - 17:00	Quadrangle 1042 (K-E15-1042)
38	4365	W17A	Wed	17:00 - 19:00	Quadrangle 1042 (K-E15-1042)
39	4366	W19A	Wed	19:00 - 21:00	Library 176A (K-F21-176A)

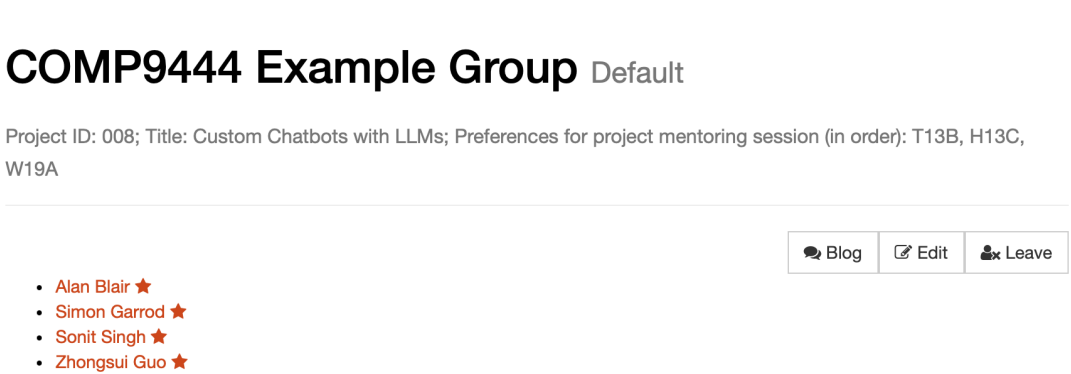
How to form groups on WebCMS

- Go to **WebCMS3** > **Group** > **Create/Join**
- Enter **Group Name** (Give a sensible name)
- Enter Details:
  - **Project ID**
  - **Title**
  - **Preferences for project mentoring session (in order)**

How to form groups on WebCMS



What we can see on WebCMS



We will use this information to move your group to a particular session so that you can join project mentoring session as a group from Week 7.

Group Project

List of projects will be provided and students have the flexibility to choose one.

Project Title: Insect pest specifies identification.

Area of Research: Computer Vision

Problem Statement: Insect pest classification plays a crucial role in various domains, including agriculture, pest control, and ecological research. Rapid and accurate identification of insect pests is essential for effective pest management strategies, early detection of invasive species, and preservation of crop yield and quality. However, manual classification of insects based on visual inspection can be time-consuming, error-prone, and challenging, particularly when dealing with conditions in the wild. The goal of this project is to correctly identify the species of insects in an automated manner using advanced artificial intelligence algorithms which has high accuracy, robust to varying environmental conditions, appearance, and deploying these algorithms for real-time monitoring.

Dataset:

Figure 1. Example images of the IP102 dataset. Each image belongs to a different species of insect pests.

The IP102 dataset [1] is a benchmark dataset for insect pests. The details about the dataset can be found in [1] and be downloaded from the URL given below:

Dataset URL: https://github.com/xpwu95/IP102/tree/master

Task: To develop an automatic insect recognition system using neural networks and deep learning which provides high accuracy, robust to varying appearance and similarity between different insect species, and faster so that it can be deployed in the real world.

Relevant Papers

[1]. X. Wu, C. Zhan, Y.-K. Lai, M. -M. Cheng and J. Yang, "IP102: A Large-Scale Benchmark Dataset for Insect Pest Recognition," *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, Long Beach, CA, USA, 2019, pp. 8779-8788, doi: 10.1109/CVPR.2019.00899.
https://ieeexplore.ieee.org/document/8954351
https://openaccess.thecvf.com/content_CVPR_2019/papers/Wu_IP102_A_Large-Scale_Benchmark_Dataset_for_Insect_Pest_Recognition_CVPR_2019_paper.pdf

[2]. A. Setiawan, N Yudistira, and R.C. Wihandika, "Large scale pest classification using efficient Convolutional Neural Network with augmentation and regularizers", Computers and Electronics in Agriculture, Vol. 200, Sept 2022.
https://www.sciencedirect.com/science/article/pii/S0168169922005191

[3]. W. Linfeng, L. Yong, L. Jiayao, W. Yunsheng, and X. Shipu, "Based on the multi-scale information sharing network of fine-grained attention for agricultural pest detection", PLOS ONE 18(10):e0286732.
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0286732

[4]. An J, Du Y, Hong P, Zhang L, Weng X., "Insect recognition based on complementary features from multiple views", Scientific Reports. 2023 Feb;13(1):2966. DOI: 10.1038/s41598-023-29600-1.
https://europepmc.org/article/pmc/pmc9940688

[5]. S. Kar, J. Nagasubramanian, D. Elango, M. E. Carroll, C. A. Abel, A. Nair, D.S. Mueller, M. E. O'Neal, A. K. Singh,

PyTorch

We will be using PyTorch for implementing neural networks in this course. Please try to install equal or later versions on your own machine.

python3 3.11.2 torch 1.13.0
numpy 1.24.2 sklearn 1.2.1

Anaconda is the recommended package manager since it installs all dependencies. Please install anaconda depending on your operating system.
Anaconda
Getting started with PyTorch

We are going to make heavy use of Jupyter Notebooks for demos and showcasing code examples. Jupyter Notebook holds text, code, and output, all in the same file, making it really a great document. You can read more about Jupyter Notebooks on the project website Jupyter.

Hardware acceleration for deep learning

- This course will require coding and running tasks that involve heavy numerical computing, such as multiplication of large number of matrices. Although part of the content can be follow along using a standard personal computer or laptop having PyTorch installed on it. However, we anticipate that training deep learning algorithms from scratch or running a pretrained network, and doing assessments will require a CUDA-enabled GPU machine.
- Note that currently only NVIDIA's graphics cards support CUDA and cuDNN libraries, and hence can be used accelerated training of deep learning algorithms.
- Cloud based options: Google Colab

Week 1 (Tutorial)

- Tutorials available on: WebCMS3 $>$ Course Work $>$ Tutorials
- Tutorials will be available on Friday (for next week's tutorial)
- **Checkpoint #1**: Python Refresher and Tensor Basics

  In the last 40 minutes of the Week 1 Tutorial, you will work on refreshing Python and learning basics of Tensors. Login to the Ed platform and go through Week 0 coding exercises, namely, **Python refresher**, **Numpy refresher**, **Matplotlib refresher**, **Google Colab refresher**, and **Week 1c: Tensors** Exercises. **After you finish these exercises, show this to your tutor as a checkpoint for this tutorial**.

Week 2 (Tutorial)

- Apart from tutorial questions, **we will be read and have a discussion on a research paper**
- The goal is to analyse the paper from a variety of different vantage points. During these tutorial sessions, students will be forming groups of 4 to 5, **each student with assigned role will provide one particular perspective**.
- Everyone in the class should participate.
- Paper discussions will be moderated by tutors.

The Roles

- Archaeologist
- Social Impact Assessor
- Industry Practitioner
- Researcher
- Scientific Peer Reviewer

Inspired by: Colin Raffel and Alec Jacobsen's Role-playing Paper Reading Seminars

Plagiarism

- Plagiarism is taken seriously by UNSW/CSE and treated as Academic Misconduct. ALL work submitted for assessment must be your own work.
- For an individual assignment, collaborative work in the form of “think tanking” is encouraged, but students are not allowed to derive code together as a group during such discussions. In the case of a group assignment, code must not be obtained from outside the group.
- Plagiarism detection software may be used on submitted work.
- Check Academic Integrity and Plagiarism

Related Courses

- COMP3411/9414 Artificial Intelligence
- COMP9417 Machine Learning and Data Mining
- COMP9418 Advanced Topics in Statistical Machine Learning
- COMP4418 Knowledge Representation and Reasoning
- COMP9491 Applied Artificial Intelligence
- COMP9517 Machine Vision
- COMP3431 Robotic Software Architecture
- COMP9727 Recommender Systems
- COMP6713 Natural Language Processing
- 4th Year Thesis topics

Communication

- Q+A: **Use Ed for posting any questions**. Teaching team will respond within 48 hour window.
- If you know the answer to any questions posted on Ed, please respond to other students' queries.
- Class Email: `cs9444@cse.unsw.edu.au` for any other issues
- **DO NOT USE our personal emails as you will get delayed response**. If staff is travelling, it will be delayed longer and you may not get any response for weeks.

Additional Resources

- Throughout the term, we will be providing additional resources to enhance your learning
- **WebCMS** $>$ **Additional Resources**
- Please go through these resources as they provide more in-depth explanation with good visuals
- If you find any good resources, please share them on Ed. We will add later to the list

Please cooperate

- Every term we try to improve your learning experiences by incorporating some innovative teaching strategies
- Changes so far
  - Added more Python and PyTorch exercises
  - Paper reading exercises in tutorials so that you can start project early
  - Flexibility Week (In past terms, we had mentoring sessions)
  - Case studies during lectures
  - Sample questions during lectures
- While COMP9444 teaching team will strive best to provide you enjoyable and memorable learning experiences, **please cooperate as managing a class of more than 850 students is a challenge**.

You can post your questions on the Ed Forum