COMP9444: Neural Networks and Deep Learning

Week 1: Overview

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School of Computer Science and Engineering

February 18, 2025

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COMP9444 Teaching Team

Hi, I'm Sonit Singh and I'm an AI Researcher and Educator, specialising in multimodal machine learning and its applications to variety of fields and problems. I am a proud father and a loving husband. I also enjoy bike riding and cooking :)

https://research.unsw.edu.au/people/dr-sonit-singh

COMP9444 Teaching Team

Hi, I'm Raymond Louie and I'm very passionate about bioinformatics, which is applying computational approaches to understand biological data for health and disease. Outside of work, I enjoy spending time with my cats, exercise, meditation and watching cartoons :)

https://research.unsw.edu.au/people/dr-raymond-hall-yip-louie

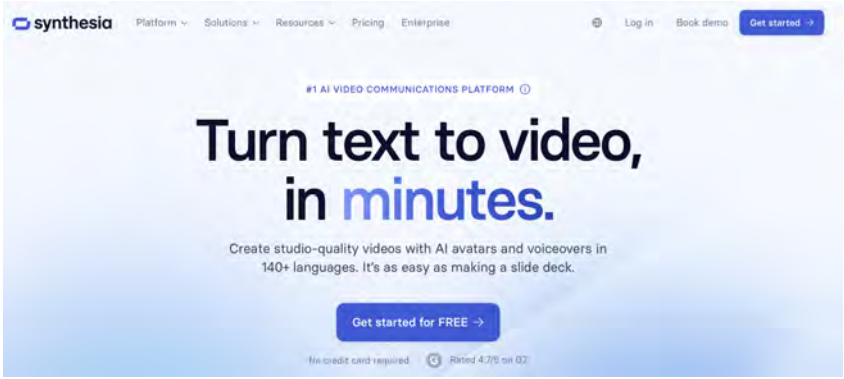
COMP9444 Teaching Team

Tutors: Fatemeh, Zahra, Deshan, Akiz, Mahmudul, Raktim, Ramya, Ziping, Zhongsui, Austin, Maher, Kiran, Feiyu, Jingying, Maryam, Irfan

Recent AI breakthroughs

Donald Trump introducing COMP9444 at UNSW Sydney!

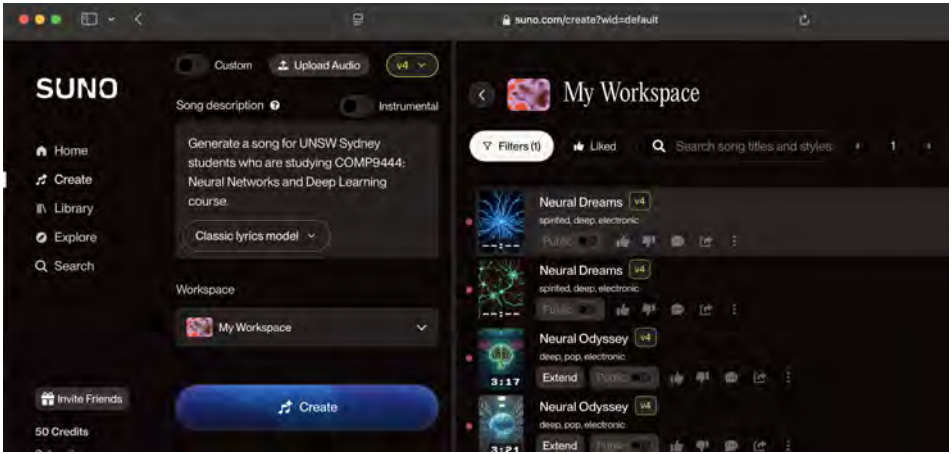
Recent AI breakthroughs



Demo: Neural Networks and Deep Learning course on Synthesia

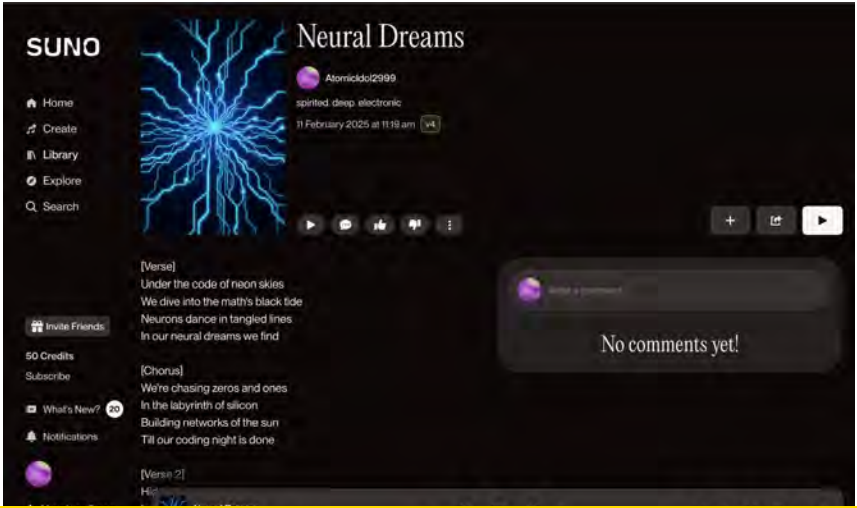
Recent AI breakthroughs

Suno song for neural network and deep learning https://suno.com/home

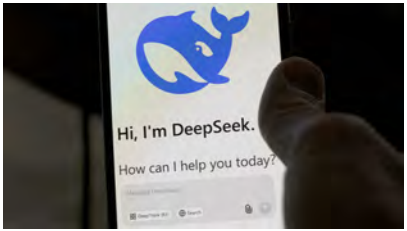


Recent AI breakthroughs

Suno song for neural network and deep learning



Recent AI breakthroughs



ANALYSIS

DeepSeek Is Reshaping China's AI Landscape

China's DeepSeek AI rattles US tech stocks

Cheaper chatbot shakes up 'AI arms race'.

DeepSeek hit by cyberattack and outage amid breakthrough success

News

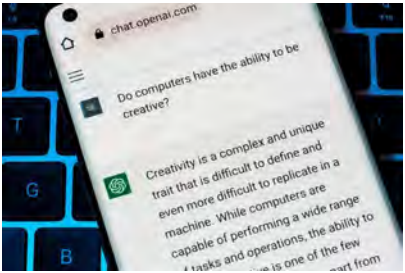
28 Jan 2025 • 4 mins

Cyberattacks | Generative AI | Security

Recent AI breakthroughs

Hello GPT-4o

We're announcing GPT-4o, our new flagship model that can reason across audio, vision, and text in real time.



- 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.

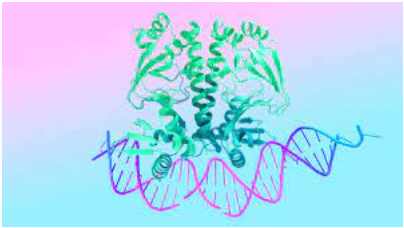
Recent AI breakthroughs

AlphaFold, a deep learning algorithm that predicts a protein's 3D structure.

The Nobel Prize in Chemistry 2024

Chemists have long dreamed of fully understanding and mastering the chemical tools of life – proteins. This dream is now within reach. **Demis Hassabis** and **John Jumper** have successfully utilised artificial intelligence to predict the structure of almost all known proteins. **David Baker** has learned how to master life's building blocks and create entirely new proteins. The potential of their discoveries is enormous.

Source: https://deepmind.google/technologies/alphafold/



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 i

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

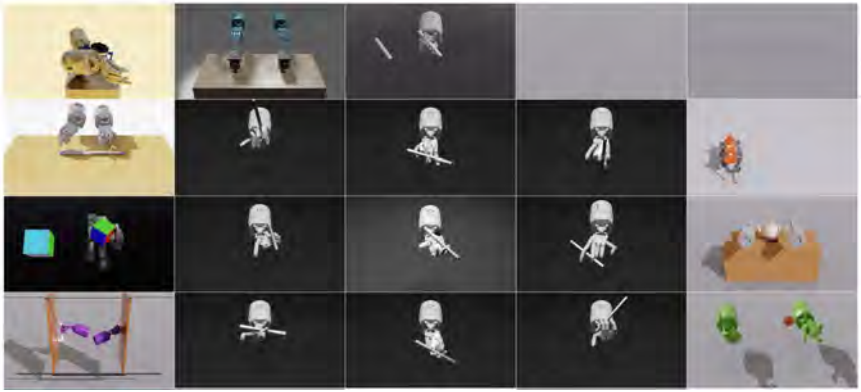
Facebook Twitter Pinterest Telegram

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

Recent AI breakthroughs

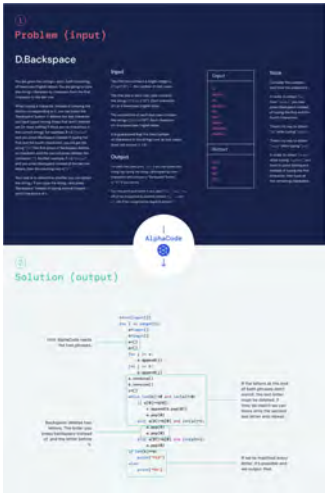
Eureka! NVIDIA Research Breakthrough Puts New Spin on Robot Learning

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



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

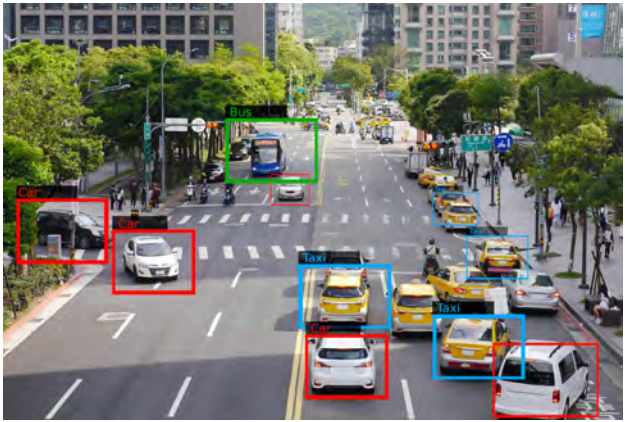
Recent AI breakthroughs



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

Recent AI breakthroughs

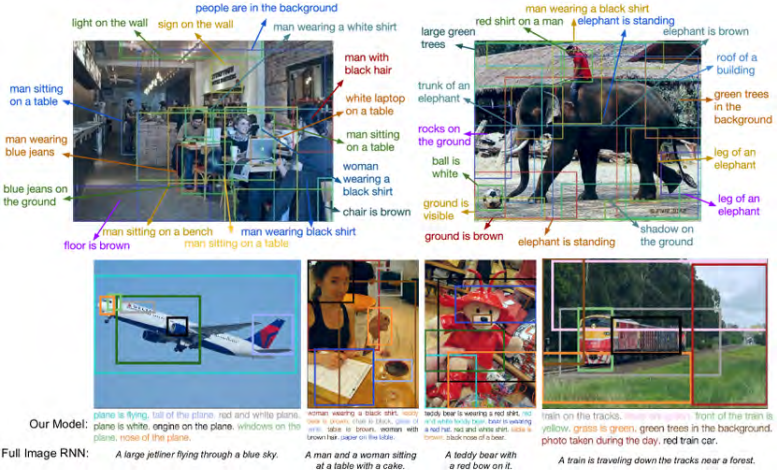
Object Detection



Source: https://www.cv-foundation.org/openaccess/content_cvpr_2016/papers/Redmon_You_Only_Look_CVPR_2016_paper.pdf

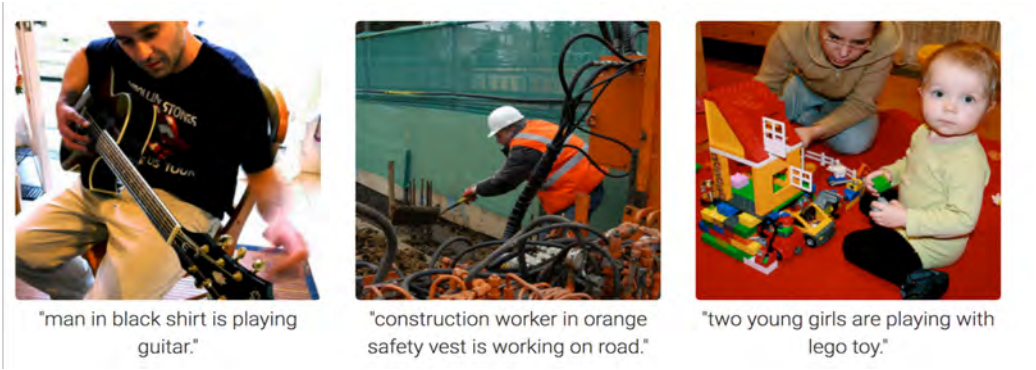
Recent AI breakthroughs

Dense Image Captioning



Recent AI breakthroughs

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



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

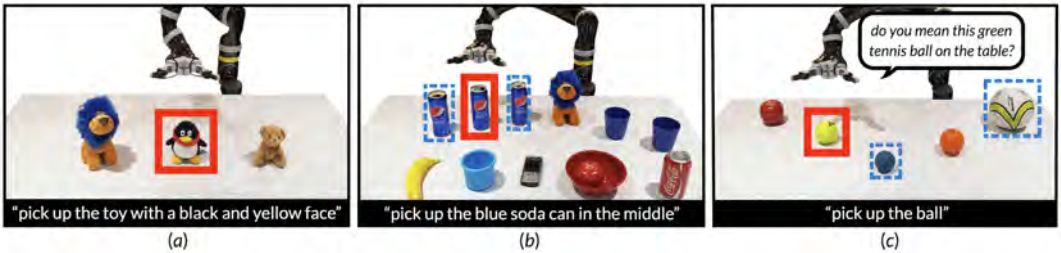
Recent AI breakthroughs

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

Source: https://visualqa.org

Recent AI breakthroughs

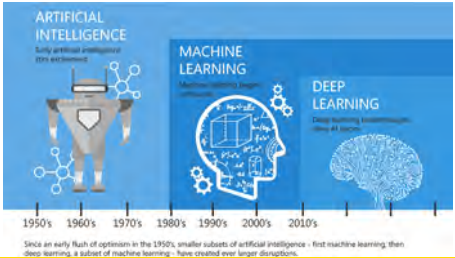
Multimodal AI: Visual grounding for referring expressions for Human-Robot Interaction



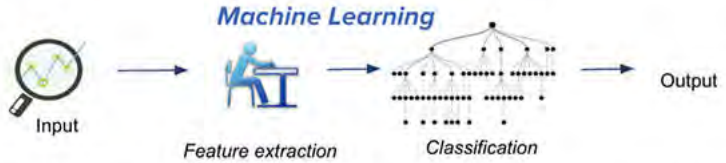
Source: https://drive.google.com/file/d/15AttCp-KCDEt8Ys5TfqXowsElm9GqAkH/view?pli=1

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



Why Deep Learning?



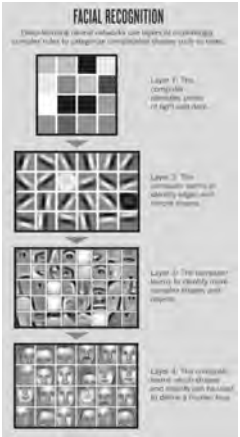
Traditional machine learning uses hand-crafted features, which is tedious and costly to develop.

Neural Networks

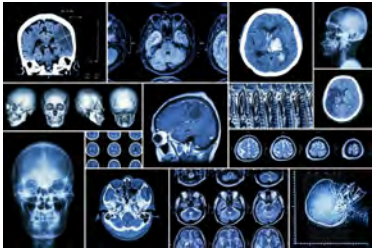
Deep learning learns hierarchical representation from the data itself, and scales with more data.

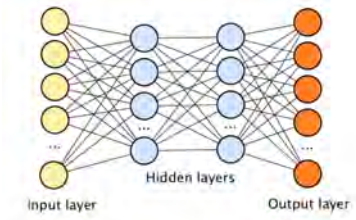
Why Deep Learning?

Key Idea: **learn hierarchy of features directly from raw data** (rather than hand-engineering them)



Why Deep Learning now and rising rapidly?





PyTorch Caffe MODELS jupyter
NVIDIA. TensorFlow
Keras dmlc XGBoost

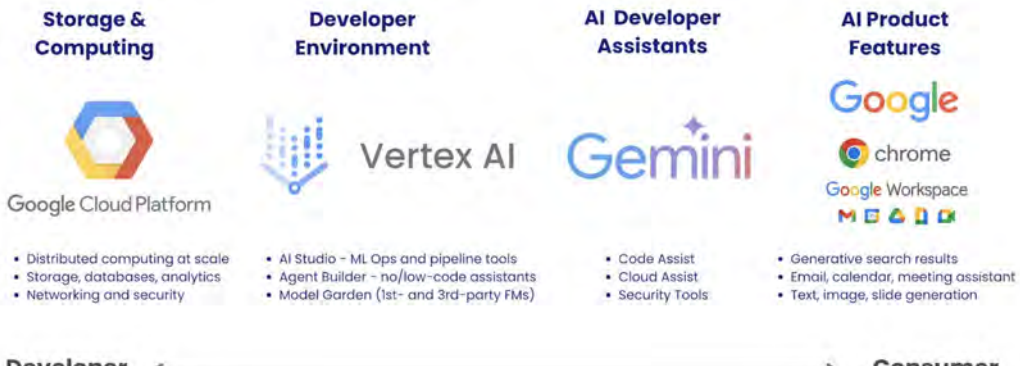
Why Deep Learning now and rising rapidly?

- 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
- Software (Frameworks), Open-source code

Deep Learning = Convergence of data, algorithms, computing power, and Open-source software

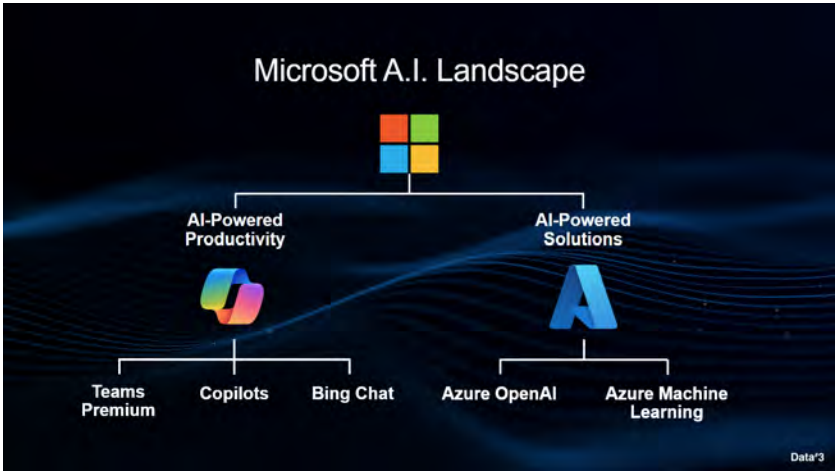
Industry

Google



Industry

Microsoft

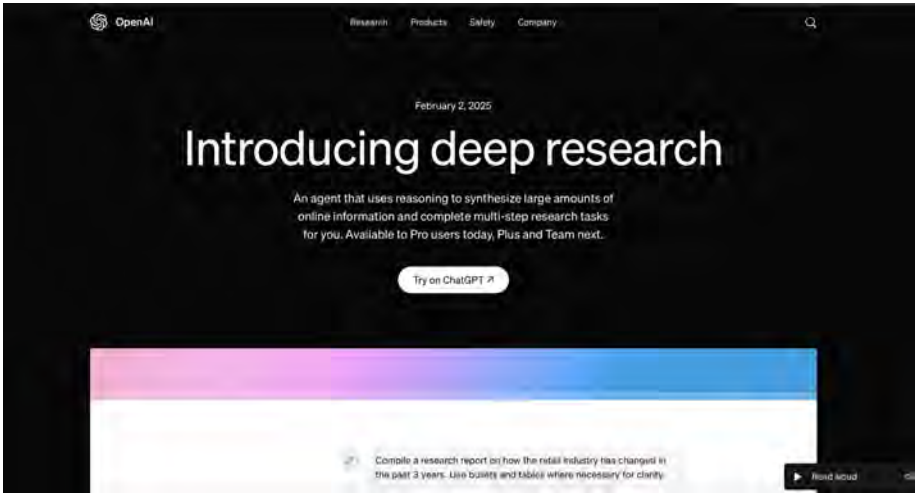


Industry

Meta

Industry

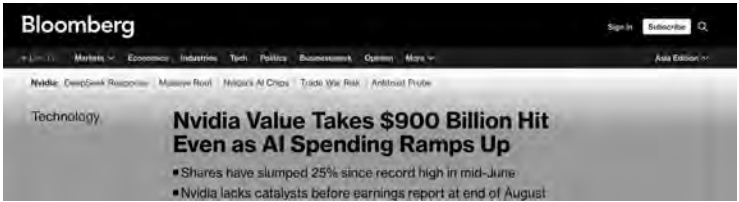
OpenAI



Industry

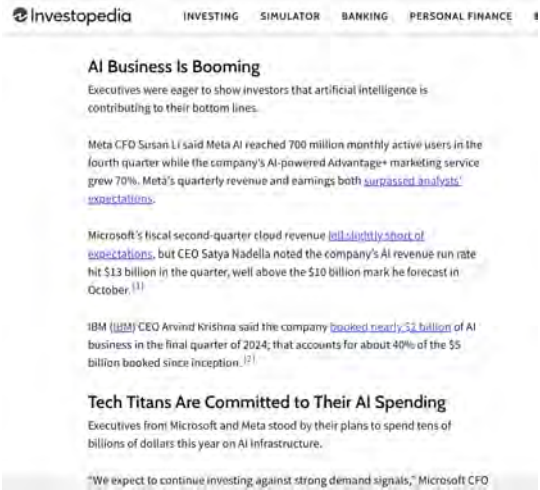
Toyota

Nvidia



Industry

AI business spending is surging!



Investopedia INVESTING SIMULATOR BANKING PERSONAL FINANCE

AI Business Is Booming

Executives were eager to show investors that artificial intelligence is contributing to their bottom lines.

Meta CFO Susan Li said Meta AI reached 700 million monthly active users in the fourth quarter while the company's AI-powered Advantage+ marketing service grew 70%. Meta's quarterly revenue and earnings both surpassed analysts' expectations.

Microsoft's fiscal second-quarter cloud revenue fell slightly short of expectations, but CEO Satya Nadella noted the company's AI revenue run rate hit $13 billion in the quarter, well above the $10 billion mark he forecast in October.[1]

IBM (IBM) CEO Arvind Krishna said the company booked nearly $2 billion of AI business in the final quarter of 2024; that accounts for about 40% of the $5 billion booked since inception.[2]

Tech Titans Are Committed to Their AI Spending

Executives from Microsoft and Meta stood by their plans to spend tens of billions of dollars this year on AI infrastructure.

"We expect to continue investing against strong demand signals," Microsoft CFO

Governments

United States

Governments

United Kingdom

UK pumps $17 billion into 'pro-growth, pro-innovation' AI plan

The AI plan includes things like establishing a national data library and designated 'growth zones'

U.K. Prime Minister Keir Starmer unveiled The AI Opportunities Action Plan, designed to bolster AI growth and development across the country. The plan, said Starmer, will help Britain become "one of the great AI superpowers."

Microsoft | Microsoft UK Stories

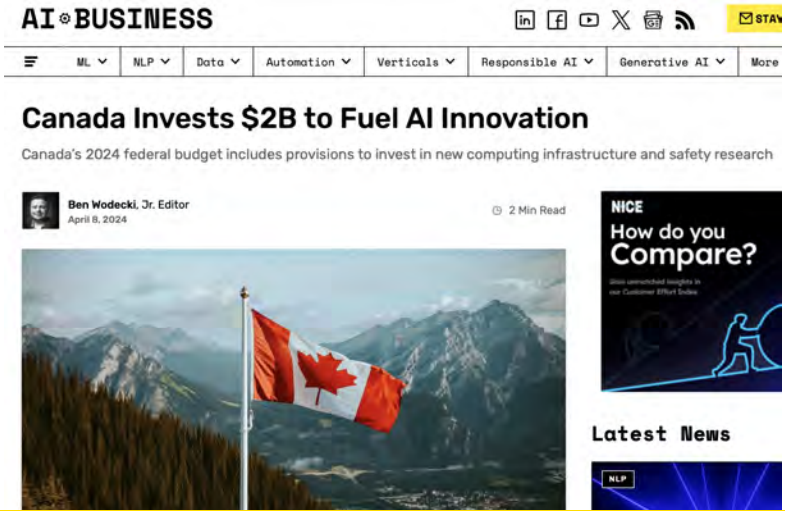
AI could boost UK GDP by £550 billion by 2035, research shows

Written by

The UK could make more than half a trillion pounds in the next decade by embracing AI and cloud technology, according to a new report commissioned

Governments

Canada



Governments

European Union

Generative AI could add $575.1 billion to the European economy by 2030.

Generative AI productivity potential in Western Europe in 2030, by sector, $ billion[1]

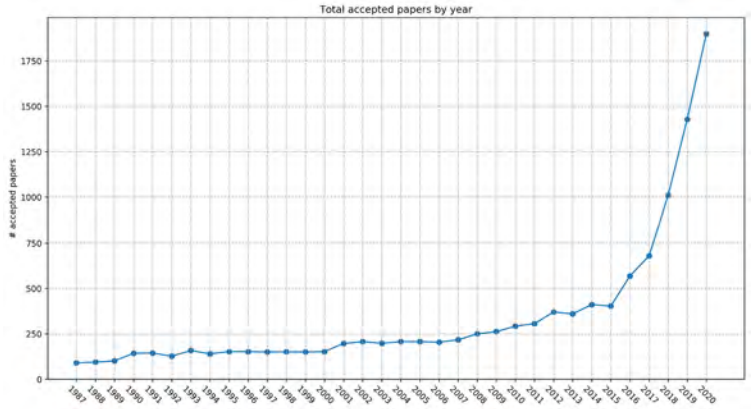
575.1
Total potential value

Governments

China

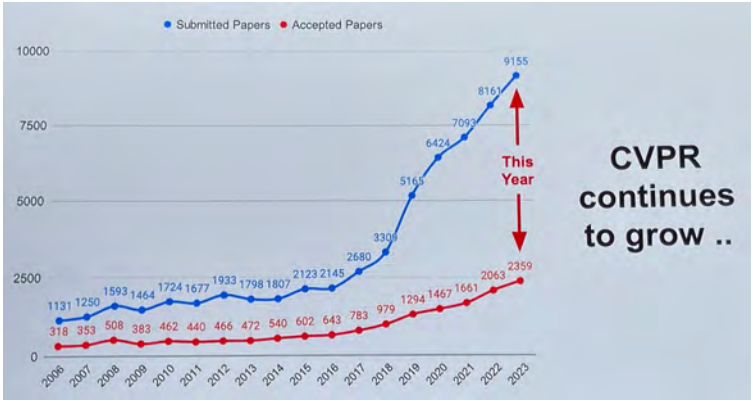
Academia

NeurIPS (Annual Conference on Neural Information Processing Systems)



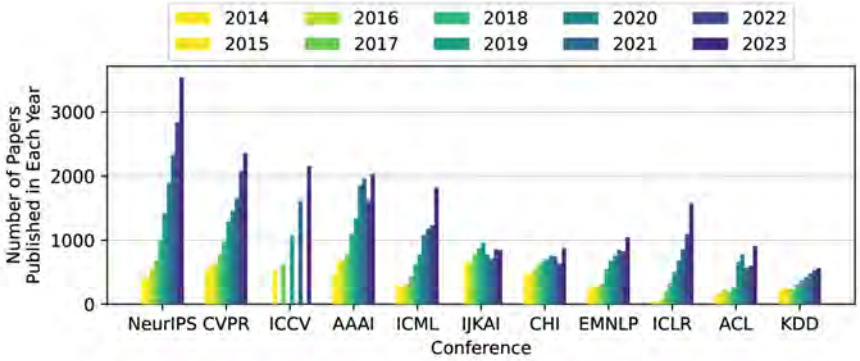
Academia

CVPR (Annual Conference on Computer Vision and Pattern Recognition)



Academia

Publication Trends in Artificial Intelligence Conferences



Source: Publication Trends in Artificial Intelligence Conferences: The Rise of Super Prolific Authors, https://arxiv.org/html/2412.07793v1

Course Web Pages

- **WebCMS**: https://webcms3.cse.unsw.edu.au/COMP9444/25T1/
- **Ed**: https://edstem.org/au/courses/20513/discussion
- **Moodle**: https://moodle.telt.unsw.edu.au/course/view.php?id=89635

Lecturers, Course Admins

- **Lecturer-in-Charge**: Dr Sonit Singh
- **Lecturer**: Dr Raymond Louie
- **Course Admin**: Fatemeh, Zahra
- **Email**: cs9444@cse.unsw.edu.au

Course Schedule

Lectures (Week 1 to Week 10)

- **Lecture A**: Tuesday; 9-11 am; E19 Patricia O'Shane 104 (K-E19-104)
- **Lecture B**: Wednesday; 11-1 pm; Mathews Theatre A (K-D23-201)

Tutorials (Week 1 to Week 5)

- Check your respective tutorial on https://timetable.unsw.edu.au/2025/COMP9444.html#S1S

Project Mentoring Sessions (Week 7 to Week 10)

- More details in next slides

CSE Help Sessions: Wednesday (2-3 pm), Library 176A

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)

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

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

Dive into Deep Learning
by Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola
Cambridge University Press, 2023
https://d2l.ai/

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 in 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) in 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

How to form groups on WebCMS

- Go to **WebCMS3** $>$ **Group** $>$ **Create/Join**
- Enter **Group Name** (Give a sensible name, no emojis please)
- Enter Details:
  - **Project ID**
  - **Title**
  - **Preferences for project mentoring session (in order), if staying in the same session, don't need to give time preference**

How to form groups on WebCMS

COMP9444 25T1

- Home
- Course Outline
- Forums
- Timetable
- Groups
- Staff

Groups

+ Create | Group Types

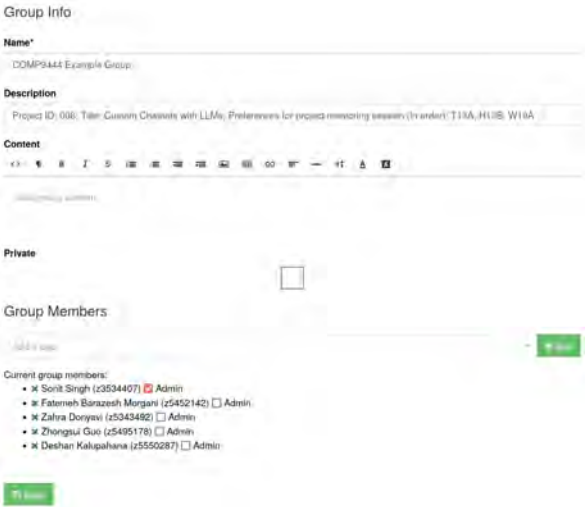
Groups you are in

Group	Group Type	
COMP9444 Example Group Project ID: 008; Title: Custom Chatbots with LLMs; Preferences for project mentoring session (in order): T13A, H13B, W19A *Members: 5*	**Default** Any groups can be created under this type	Leave

Other joinable groups

Default

How to form groups on WebCMS



What we can see on WebCMS

COMP9444 25T1

- Home
- Course Outline
- Forums
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Groups

+ Create | Group Types

Groups you are in

Group	Group Type	
COMP9444 Example Group Project ID: 008; Title: Custom Chatbots with LLMs; Preferences for project mentoring session (in order): T13A, H13B, W19A *Members: 5*	**Default** Any groups can be created under this type	Leave

Other joinable groups

Default

Group Project

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

Project Title: Insect pest species 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/stamp/stamp.jsp?tp=&arnumber=8954315
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/S0168169922005193

[3]. W. Liinfeng, 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/s41598-023-29800-1.
https://europepmc.org/article/pmc/pmc9942649

[5]. S. Kar, J. Nagasubramanian, D. Elango, M. E. Carroll, C. A. Abid, 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

Your Responsibilities

- Please read Announcement carefully (available both on Ed and WebCMS3)
- Always read Ed announcements and posts before posting any questions (someone else might have asked the same question and it was answered)
- Always use Ed posts for any questions you have regarding the course
- Please use class email cs9444@cse.unsw.edu.au if it is confidential
- When marks are released for assessments (assignment, group project, final exam), please do check and let us know within 3 working days if there are any issues. No changes in marks can be made later.

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