
4C16/5C16
Midjourney (2022)

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

00 - Introduction

François Pitié

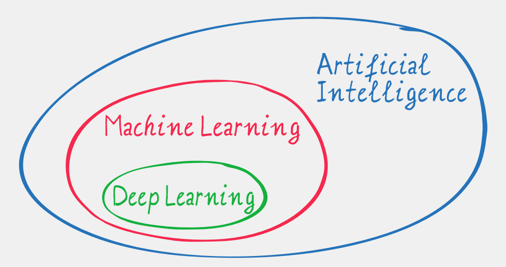
Assistant Professor in Media Signal Processing
Department of Electronic & Electrical Engineering, Trinity College Dublin

[4C16/5C16] Deep Learning and its Applications — 2025/2026

Credit: F. Pitié [Midjourney]

Deep Learning is a particular type of **machine learning** method, and is thus part of the broader field of **artificial intelligence** (using computers to reason).

Deep learning is another name for **artificial neural networks**, which are inspired by the structure of the neurons in the cerebral cortex.



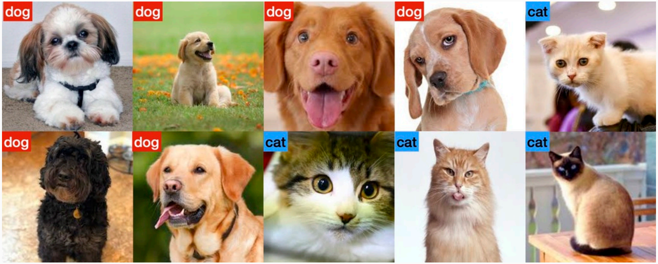
The recent quantum leap in machine learning has solely been driven by deep learning successes.

When you read or hear about AI or machine Learning successes in recent years, it really means Deep Learning successes.

Machine Learning can be split into 4 main fields:

1. Supervised Learning (95% of applications)

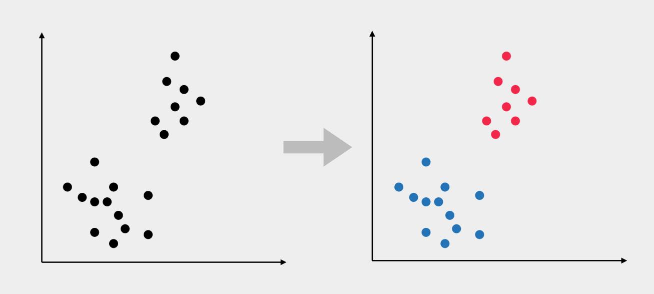
We have a labelled dataset $(\mathbf{x}_i, y_i)_{i\in\{1..n\}}$ containing features $\mathbf{x}_i$ (eg. the image pixels) and outcomes y_i (eg. cat=0/dog=1 label).



Can we find a model $f(\mathbf{x}_i) = y_i$ to predict the outcome from the input features?

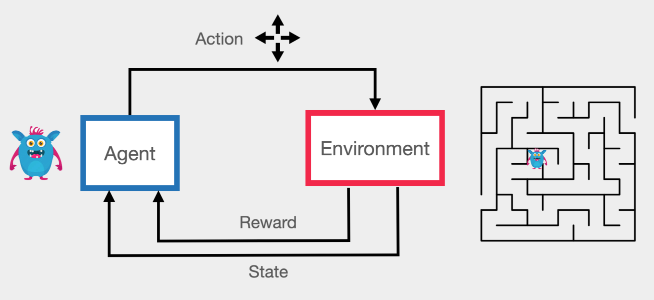
2. Unsupervised Learning (3% of applications)

What can we learn about a dataset ($\mathbf{x}_i$) by just looking at it? (ie. without any labelled information y_i)



3. Reinforcement Learning (0.001% of applications)

How can an agent interact with its environment (the data) to get maximum reward (eg. game playing, robots learning to walk)?

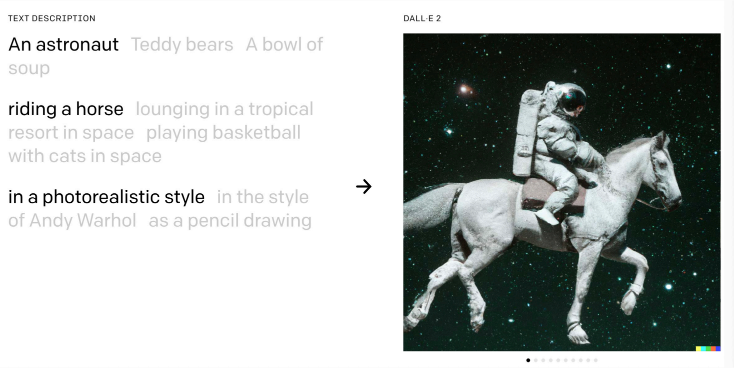


4. Generative Models (2% of applications)

The aim is to generate text, images, or other media.

Mathematically, we try to model the conditional probability of the observable $\mathbf{x}$, given a target y: $\mathbf{x} \sim p(\mathbf{x}|y)$

this is your ChatGPT, DallE, Stable Diffusions, etc.

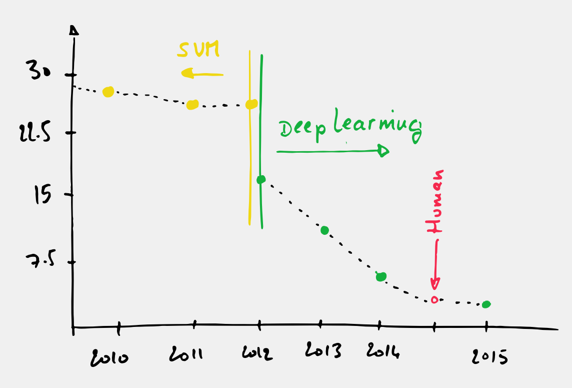


Deep Learning has made major breakthroughs in all these fields.

Early Deep Learning Successes

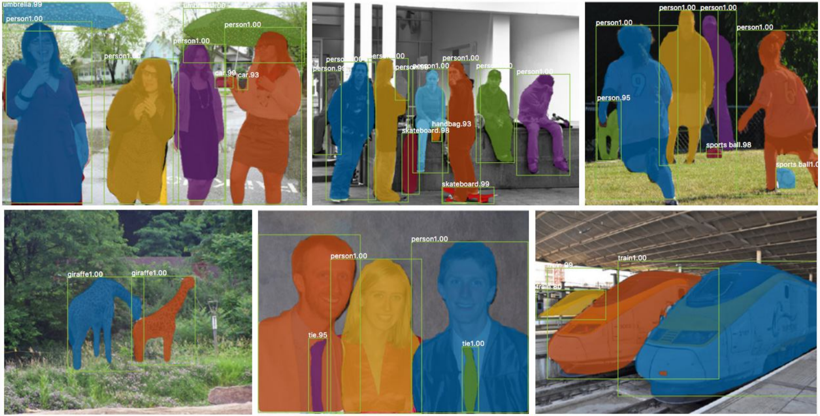
It all started in 2012 in Image Recognition, one of the core applications of Computer Vision. ImageNet [www.image-net.org] runs an annual challenge where software programs compete to correctly classify and detect objects and scenes in images.

The error rate in object recognition for that challenge has massively dropped since the introduction of deep neural networks in 2012 [1]. Machines can now do better than humans.



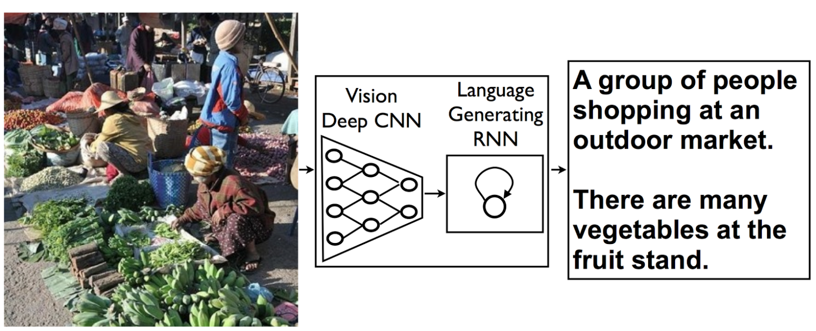
[1] ImageNet Classification with Deep Convolutional Neural Networks
A Krizhevsky, I Sutskever, G Hinton, 2012 [https://goo.gl/wxen2Y]

These neural nets have then been adapted to achieve state of the art in Scene Understanding.



[1] Mask R-CNN
Kaiming He et al., 2017 [https://arxiv.org/abs/1703.06870]

Image models combined with language models made it possible to automatically generate captions from images.



Google Research Blog (2014) [https://goo.gl/U88bDQ]

By 2016, all major tech companies had changed their machine translation systems to use Deep Learning.

Google used to average a yearly 0.4% improvement on their machine translation system. Their first attempt at using Deep Learning yielded an overnight 7% improvement! More than in an entire lifetime!

Several years of handcrafted development could not match a single initial deep learning implementation.

New York Times, “The Great AI Awakening” (2016) [https://goo.gl/DPYp6d]

The popularisation of the Transformer architecture in 2017, has given rise to Large Language Models (LLM) that have changed the face of text processing, and artificial intelligence at large.

These models contain hundreds of billions of parameters and have been trained to predict text on a extremely large corpus of Internet sources, made of hundreds of billion words, and sometimes dozen of languages.

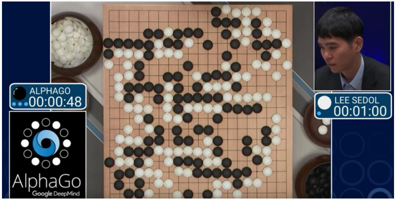
GPT-3 [1] (2020) was perhaps one of the most famous early models that has been adopted in hundreds of applications, ranging from grammar correction, translation, summarisation, Chat Bots, text generation, cheating at your homework, etc.

GTP-3 [https://openai.com/blog/gpt-3-apps/]

[1] Language Models are Few-Shot Learners
T. Brown et al., 2020 [https://arxiv.org/abs/2005.14165]

Deep learning has also been introduced in reinforcement learning to solve complex sequential decision making problems.

Recent successes include: playing old Atari computer games, programming real world Robots and beating humans at Go.



> demo: Robots Learning how to walk (2017) https://www.youtube.com/hx_bgoTF7bs
>
> DeepMind https://goo.gl/3TcCNA
>
> demo: AI-Driven, Physics-Based Character Animation (2022) https://nv-tlabs.github.io/ASE/

Reasons of a Success

Neural Networks have been around for decades. But is only now that it surpasses all other machine learning techniques.

Deep Learning is now a disruptive technology that has been unexpectedly taking over operations of technology companies around the world.

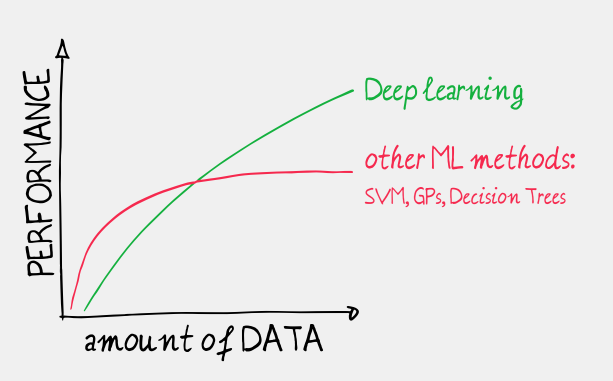
"The revolution in deep nets has been very profound, it definitely surprised me, even though I was sitting right there."

— Sergey Brin, Google co-founder

Reasons of a Success

Scale

Why now? Because Deep Learning does scale.



Reasons of a Success

Scale

Neural Nets are the only ML technique whose performance **scales efficiently with the training data size**. Other ML popular techniques just can't scale that well.

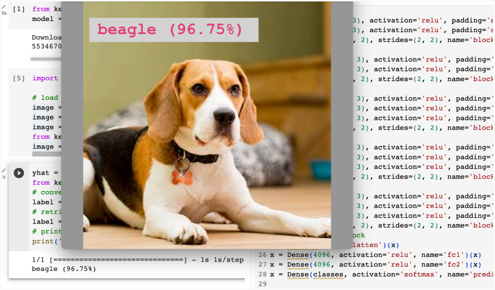
The advent of **big databases**, combined with cheaper **computing power** (Graphic Cards), meant that Deep Learning could take advantage of all this, whilst other techniques stagnated. Instead of using thousands of observations, Deep Learning can take advantage of billions.

The tipping point was 2012 in Computer Vision and around 2014 in Machine Translation.

Reasons of a Success

Simplicity

Deep Learning offers a (relatively) simple framework to define and parameterise pretty much any kind of numerical method and then optimise it over massive databases.



You can build a powerful image recognition model in about 20 lines of code [VGG16]

Reasons of a Success

Universality

The universality of Deep Learning is actually astonishing. The same framework can be used in many fields. Which means that the same framework can tackle extremely complex applications. We can now combine information coming from pretty much any signal, eg. audio, text, images, stock market, twitter feeds, etc.

Reasons of a Success

Global Reach

It has been applied successfully to many fields of research, industry and society:

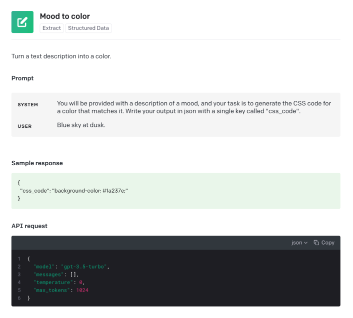
self-driving cars, image recognition, detecting cancer, speech recognition, speech synthesis, machine translation, drug discovery and toxicology, customer relationship management, recommendation systems, bioinformatics, advertising, controlling lasers, etc.

> demo: Physics Simulation Prediction https://youtu.be/KfZFgSff9N8
>
> AlphaFold: predict the shape of a protein
> https://www.deepmind.com/research/highlighted-research/alphafold

Reasons of a Success

Democratisation

Programmers can train state of the art neural nets without the 10+ years expertise in the domain and nowadays AI tools can build applications from a simple prompt in plain English.



openAI prompt [https://platform.openai.com/examples/default-mood-color]

It is an opportunity for start-ups and an ubiquitous tool in tech companies.

Impact

Here is a question for you:

How long before your future job gets replaced by an algorithm?

BBC Sign in Home News Sport Reel Worklif

NEWS

Home | War in Ukraine | Climate | Video | World | UK | Business | Tech | Science | Entert

Tech

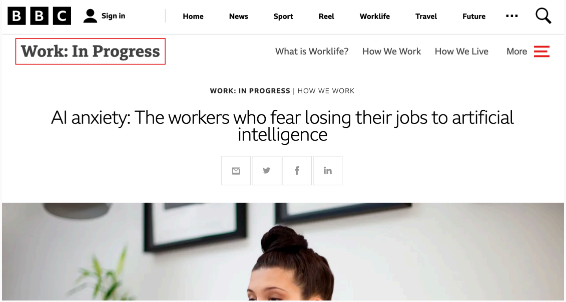
AI could replace equivalent of 300 million jobs - report

28 March

GETTY IMAGES

By Chris Vallance
Technology reporter

Artificial intelligence (AI) could replace the equivalent of 300 million full-time jobs, a report by investment bank Goldman Sachs says.



BBC Sign in Home News Sport Reel Worklife Travel Future

Work: In Progress

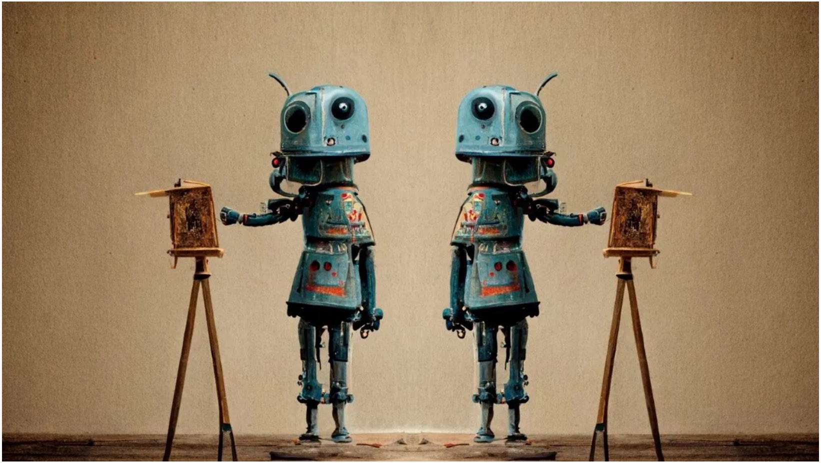
What is Worklife? How We Work How We Live More

WORK: IN PROGRESS | HOW WE WORK

AI anxiety: The workers who fear losing their jobs to artificial intelligence

Impact

What are the job prospects for an artist?



Credit: Louis Rosenberg [Midjourney]

Final Words

Yes, self-driving cars are not quite there yet...

Final Words

Yes, self-driving cars are not quite there yet...

Final Words

Yes, self-driving cars are not quite there yet...

Final Words

… but maybe not too far

Self-driving cars

This article is more than **1 year old**

California allows driverless taxi service to operate in San Francisco

The robotic electric cabs will be restricted to less congested times and places until regulators can assess its safety

Associated Press

Fri 3 Jun 2022 16.54 BST

Cruise has been operating in parts of San Francisco in autonomous vehicles with a back-up human driver. Photograph: Paul Sancya/AP

Final Words

And, no, machines haven't become self-aware...

Google fires software engineer who claims AI chatbot is sentient

Company said Blake Lemoine violated Google policies and that his claims were 'wholly unfounded'

Google say LaMDA is simply a complex algorithm designed to generate convincing human language. Photograph: Andrew Kelly/Reuters

Final Words

… but whether these systems are intelligent or not,

(and what does that even mean?),

these new Large Language Models do seem to be able to build complex models of the world and are not just stochastic parrots repeating memorised statistical patterns.

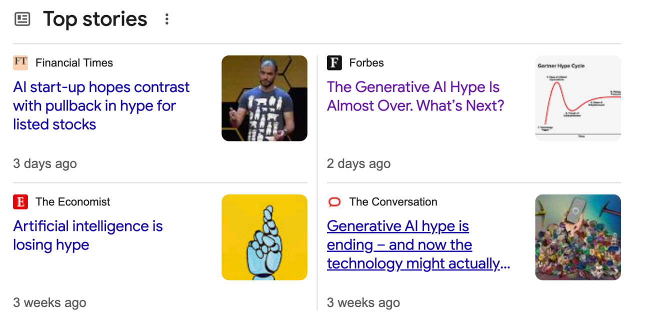
Proof that AI Understands? Emergent World Representations [https://youtu.be/9AxRIuzlUV0]

Final Words

Note that we haven't yet hit the limits of what Deep Learning has to offer.

Final Words

Note that we haven't yet hit the limits of what Deep Learning has to offer.



Admittedly, we are going through the usual hype cycle.

Final Words

In a way, the increased awareness of the societal and ethical concerns raised by the use at scale of these new technologies, and the existential fears it has sparked, are further evidence of the significance of this revolution.

4C16: Course Structure

Course Content

Part 1. Machine Learning Fundamentals

In Week 1-4, we will cover

Least Squares: the root of all Machine Learning.
(feature mapping, over/under fitting, regularisation, maximum likelihood)

Logistic Regression: your first Neuron.
(linear classifier, cross-entropy , gradient descent optimisation)

Classic Classifiers: overview of classic machine learning algorithms.
(SVM, Decision Trees, Kernel Trick, Nearest-Neighbours)

Comparing Classifiers:
(ROC curves, confusion tables, F1 score)

Course Content

Part 2. Neural Net Fundamentals

Feedforward Neural Network
(network architecture, back-propagation, regularisation, vanishing gradients)

Convolutional Neural Network
(convolution layers, pooling, visualisation, knowledge transfer)

Generative Models
(unsupervised learning, Variational AutoEncoders, GANs)

Recurrent Neural Network
(LSTM, word embedding, text processing)

Transformers & Large Language Models
(text processing, multimedia fusion)

Assignments [provisional]

Week 1	lab 0: Getting grips with the system	
Week 2	lab 1: Least Squares lab	
Week 3	lab 2: Logistic Regression lab	
Week 4	lab 3: Classifiers lab	
Week 5	lab 4: Feed Forward Neural Nets lab	
Week 6	lab 5: Convolutional Neural Nets lab	
Week 8-10	interviews (labs 1-5)	[10% mark]
Week 8-10	lab 6: mini-project	
Week 11-12	interviews (mini-project)	[10% mark]
Midterm		[20% mark]
Exam		[60% mark]

More information will be given to you on BlackBoard.

Labs

We have developed a web based environment specially for you, so that you can learn best industry practices.

You will be programming in python 3 using Pytorch. Everything will be running on Colab, which gives you on-demand scalable computing resources and you will use Git to checkpoint your progress and for continuous feedback on lab assignments.

TA's will conduct two sets of individual interviews about your labs.

Timetabling

Lectures:

Mondays 9-10 (Synge Arts Block)
Tuesdays 10-11 (D'Olier St, Lower Lecture Theatre, School of Nursing)
Thursdays 10-11 (Chemistry Lecture Theatre, Chemistry Building)

Labs:

you will need to attend one of these 4 slots:

Wednesdays 9-10 (Cadlab, AAP)
Wednesdays 10-11 (Cadlab, AAP)
Wednesdays 11-12 (Cadlab, AAP)
Fridays 11-12 (Cadlab, AAP)

More information will be given to you on BlackBoard.

Books & Resources

The web is full of excellent resources on Deep learning and AI. Here are a few links that I found useful while writing the course material:

[1] Deep Learning (MIT press) — Ian Goodfellow et al. https://www.deeplearningbook.org

[2] Machine Learning on Cousera — Andrew Ng https://www.coursera.org/learn/machine-learning

[3] Neural Networks and Deep Learning — Michael Nielsen http://neuralnetworksanddeeplearning.com/

[4] Deep Learning with Python — F. Chollet https://www.manning.com/books/deep-learning-with-python

[6] Brandon Rohrer's YT channel https://www.youtube.com/@BrandonRohrer

[8] Wes Roth's YT channel for News on AI https://www.youtube.com/@WesRoth

[9] Matt Wolfe's YT channel for News on AI https://www.youtube.com/@mreflow

[5] Curated list of links https://github.com/ChristosChristofidis/awesome-deep-learning


Happy New Year
to you all!
Credit: F. Pitié [Midjourney]