Introduction to Machine Learning

INTRODUCTION TO DEEP LEARNING

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NORTHIN SUMMER SCHOOL

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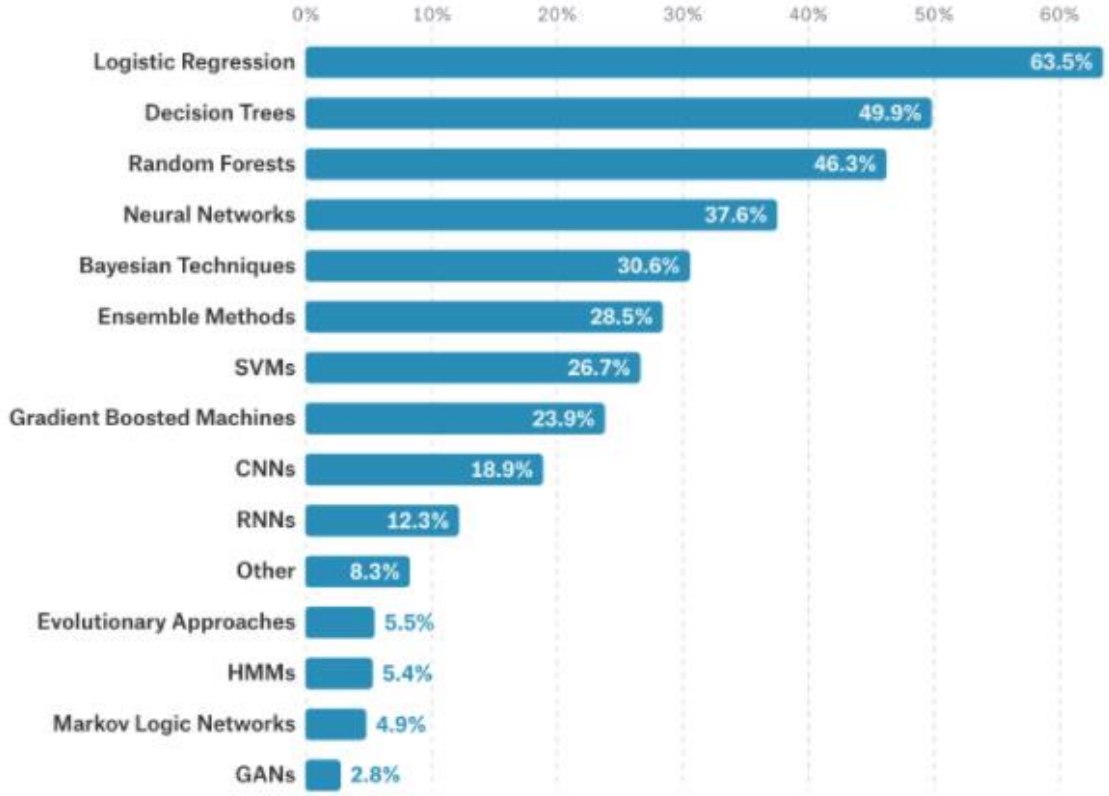
The use of Machine Learning

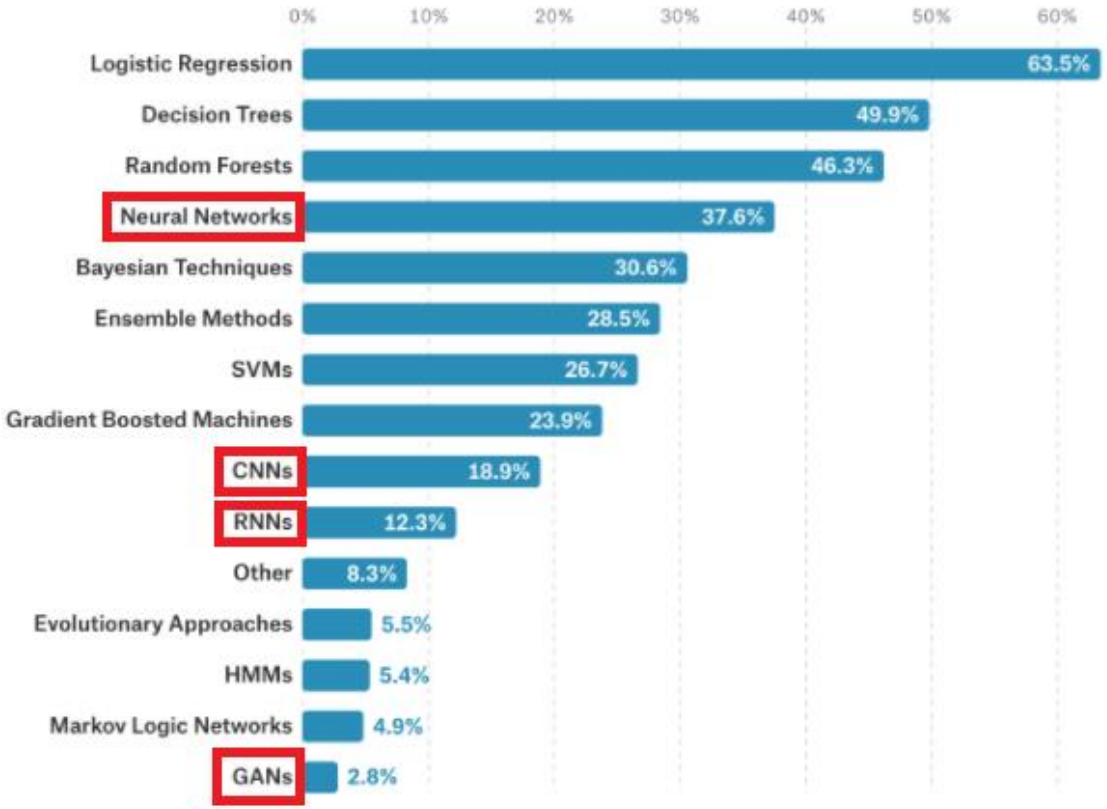
Kaggle's 2017 survey



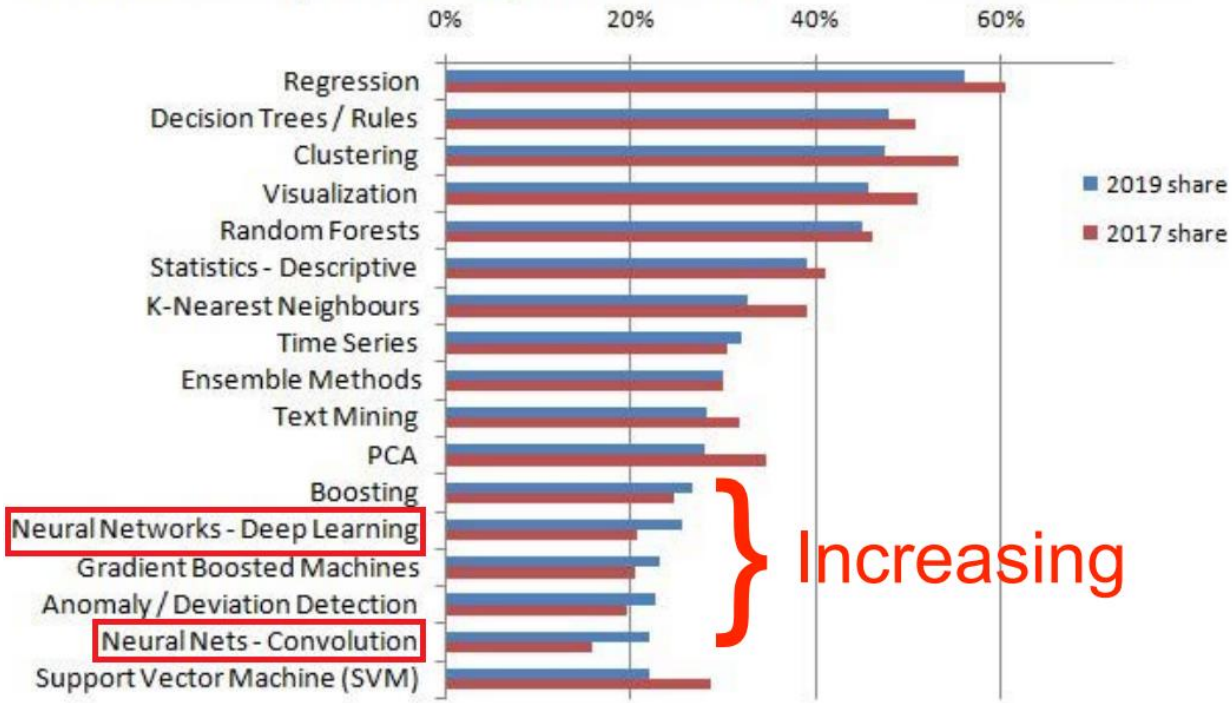
Kdnuggets 2018/9 vs 2017 survey

The use of Machine Learning

Kaggle's 2017 survey

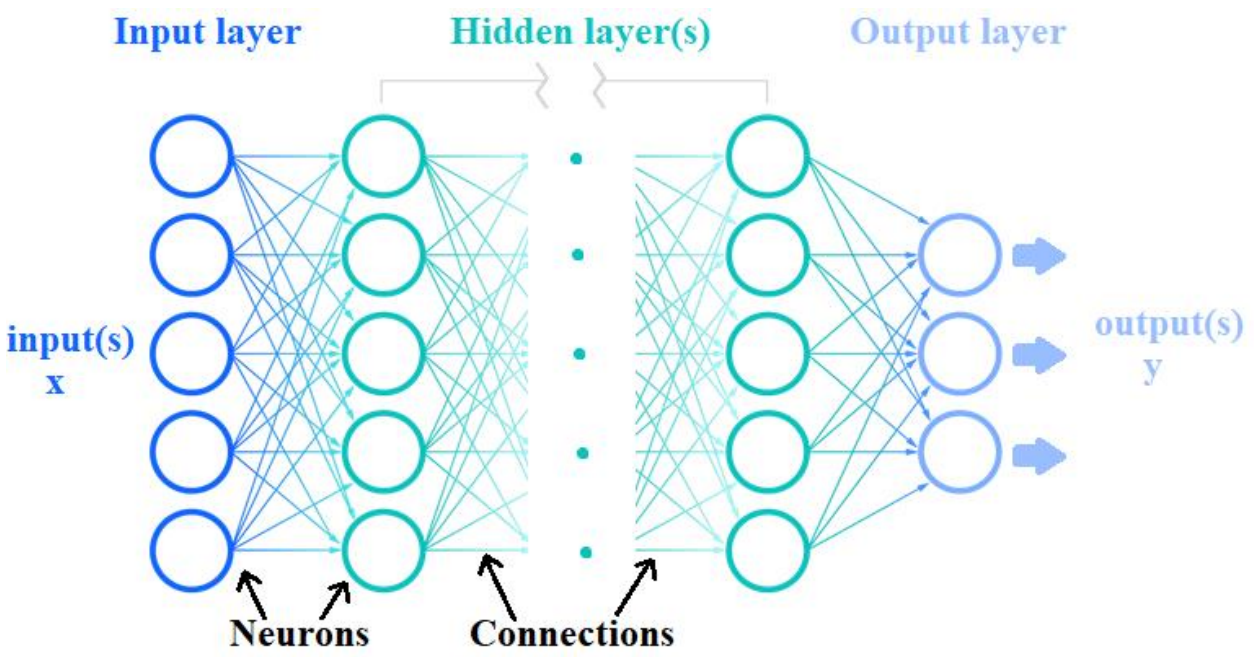


Kdnuggets 2018/9 vs 2017 survey



Neural networks: overview

- Subset of machine learning, the heart of Deep learning algorithms
- Able to recognize very complex patters (used for image, text and audio data)



Source: IBM

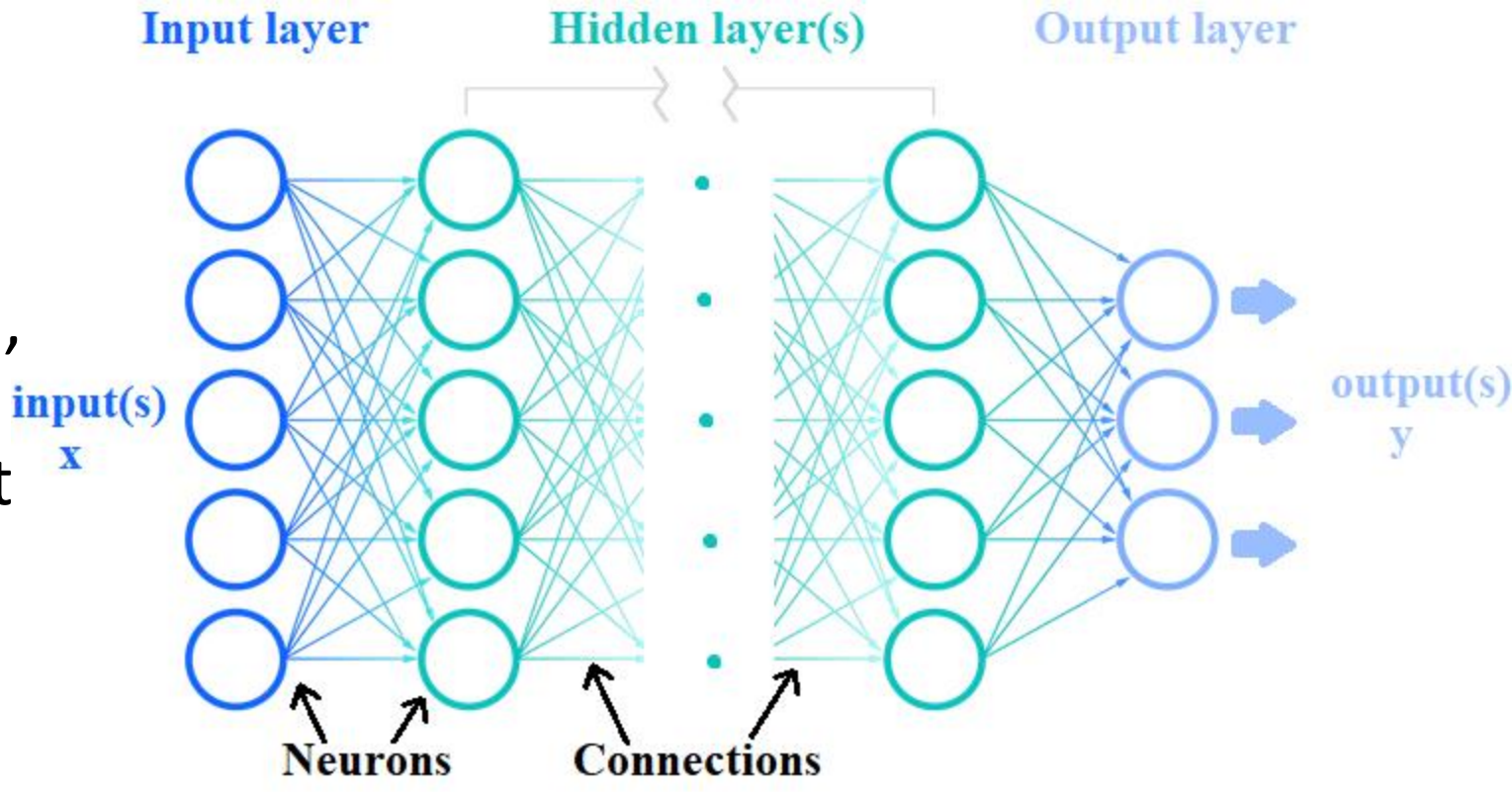
Neural networks: types

- Types or different architectures of neural networks
  1. **Feedforward Neural Networks**: Tabular datasets
  2. **Recurrent Neural Networks** (RNN): Sequential data such as text or audio
  3. **Convolutional Neural Networks** (CNN): Image and video processing
  4. **Transformers**: Text, audio and image processing

- Deep Learning is the use of models that have a neural network architecture with a huge amount of layers
- Commonly the three types of architectures are combined into bigger models!

Feedforward neural networks

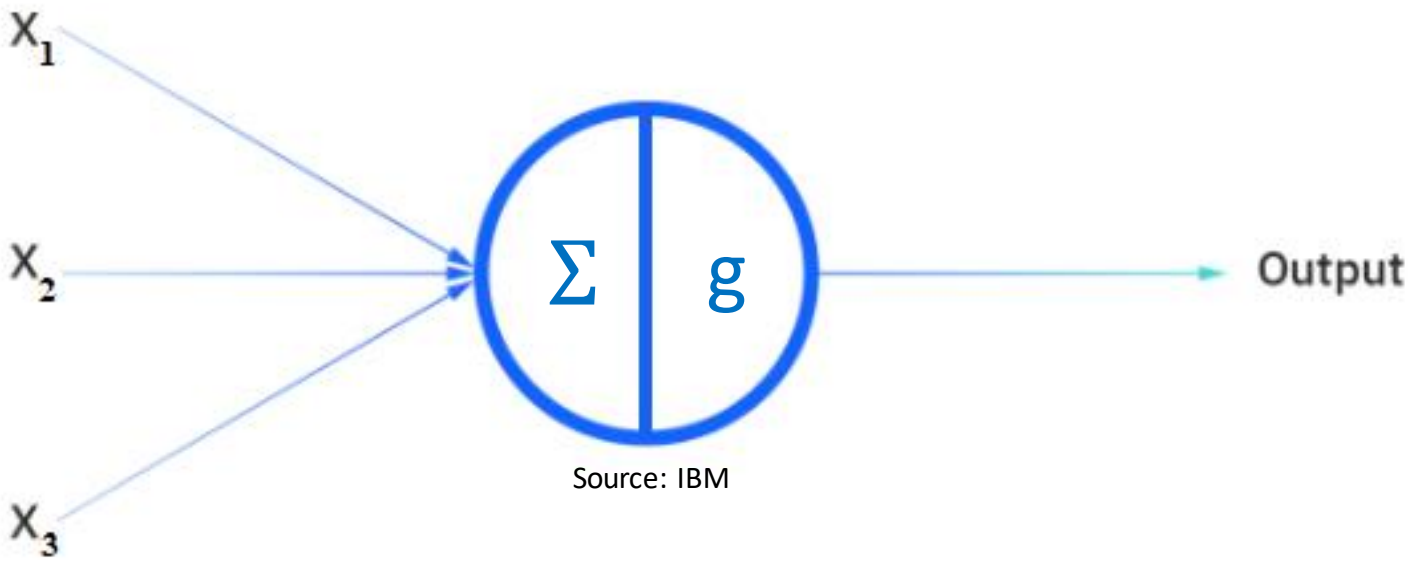
- Each node has an associated weight, threshold, and activation function
- If node output > threshold, neuron is “activated”, passes information to next layer



Source: IBM

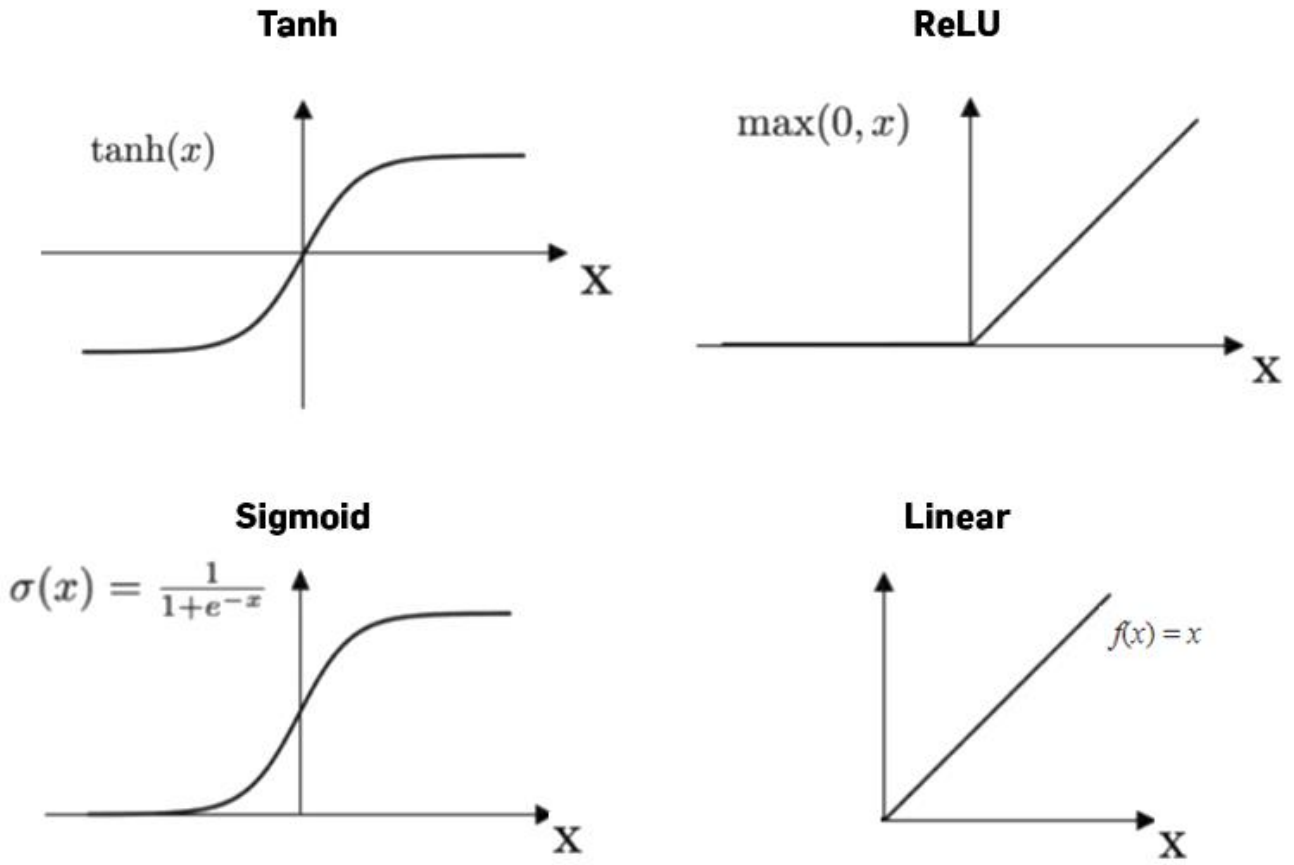
Feedforward neural networks

- We can think of each node as a single **linear regression** + **activation function**
- Input vector x → $\sum_{i=1}^{n} \beta_i x_i + \beta_0$ → $g(\sum_{i=1}^{n} \beta_i x_i + \beta_0)$



Source: IBM

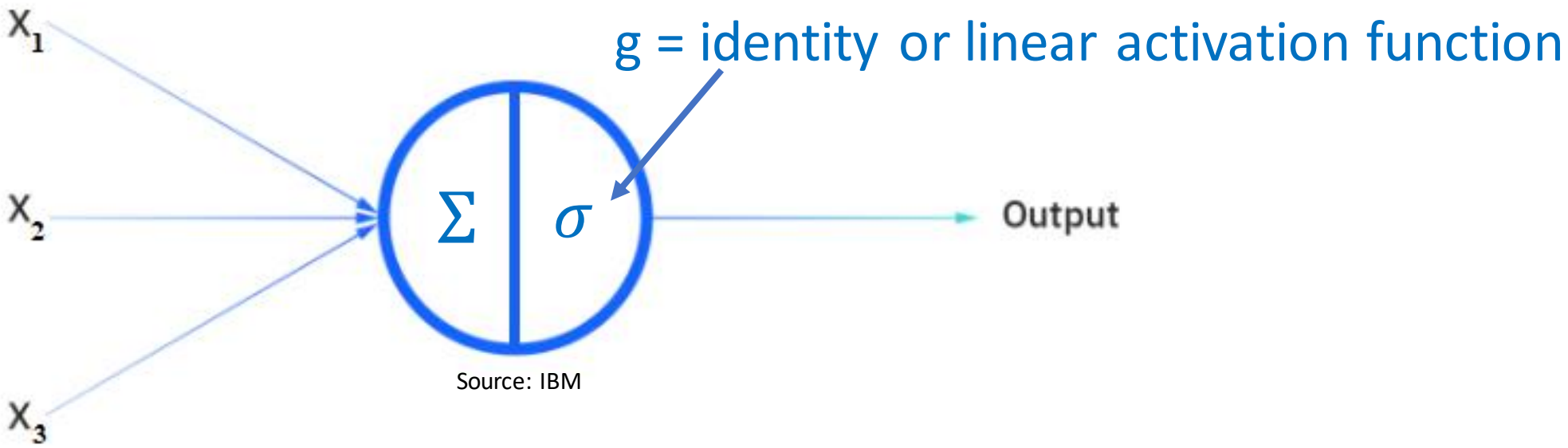
Types of activation functions



And many more…
active research topic!

Linear regression as a neural network?

- Neural network of 2 layers and a **single neuron** with a **linear activation function**
- Input vector x → $\sum_{i=1}^{n} \beta_i x_i + \beta_0$ → $g(\beta^T x) = \beta^T x$

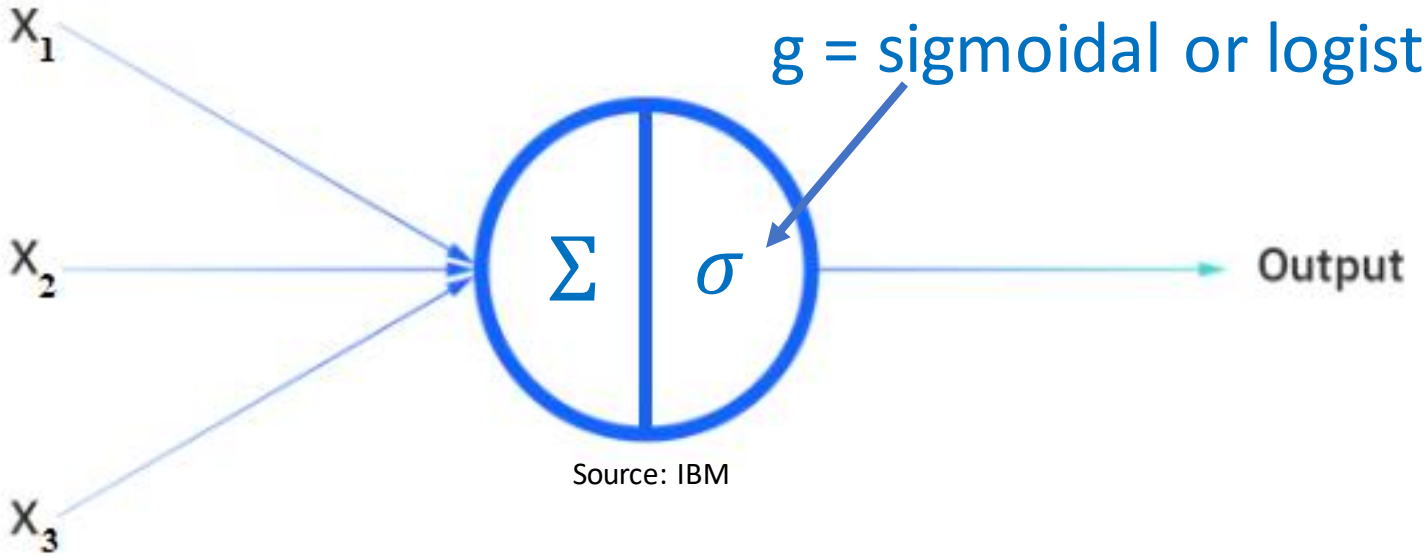


Source: IBM

Feedforward NN: simple perceptron

- Neural network of 2 layers and a **single neuron** with a **sigmoid activation function**
- Input vector x → $\sum_{i=1}^{n} \beta_i x_i + \beta_0$ → $g(\beta^T x) = \frac{1}{1+e^{-\beta^T x}}$

g = sigmoidal or logistic function



Source: IBM

Feedforward NN: simple perceptron

- Input vector x → $\sum_{i=1}^{n} \beta_i x_i + \beta_0$ → $g(\beta^T x) = \frac{1}{1+e^{-\beta^T x}}$
- Quiz: Does perceptron recall you any other algorithm/model?

Feedforward NN: simple perceptron

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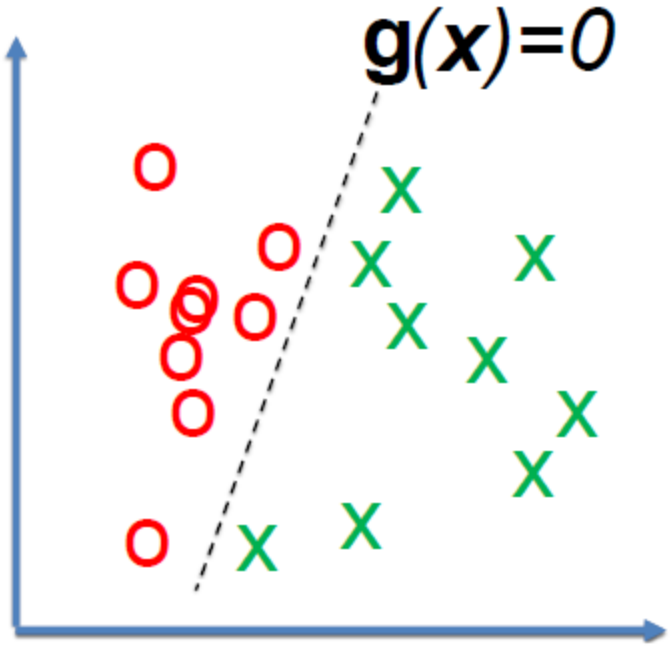
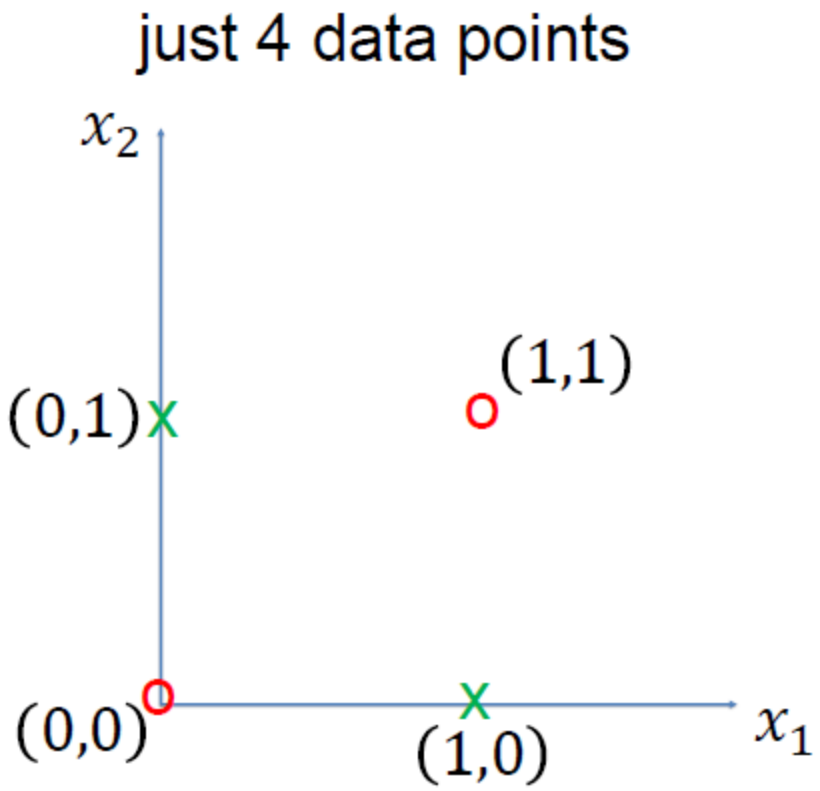
Logistic regression

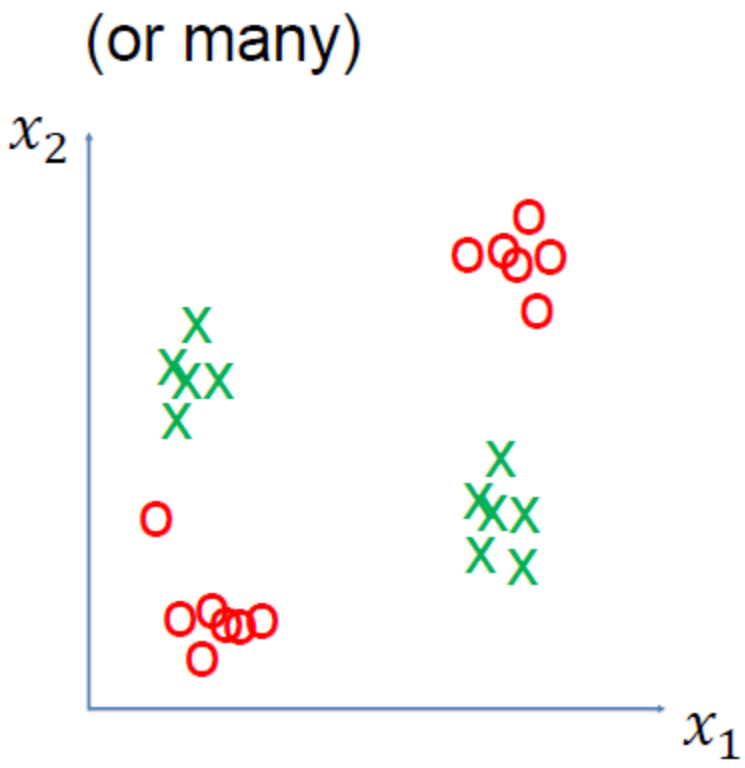
- Simple perceptron "=" logistic regression
- Simple perceptron performs **linear separation**



What about non-linear separable tasks?

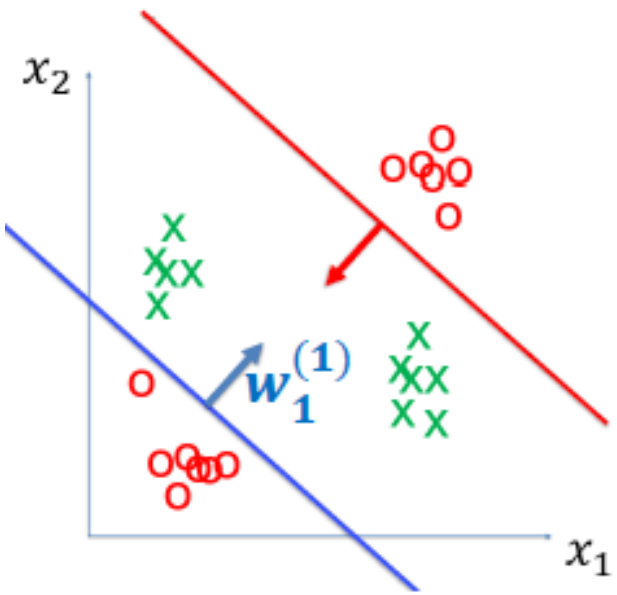
- Classical XOR problema, not linearly separable

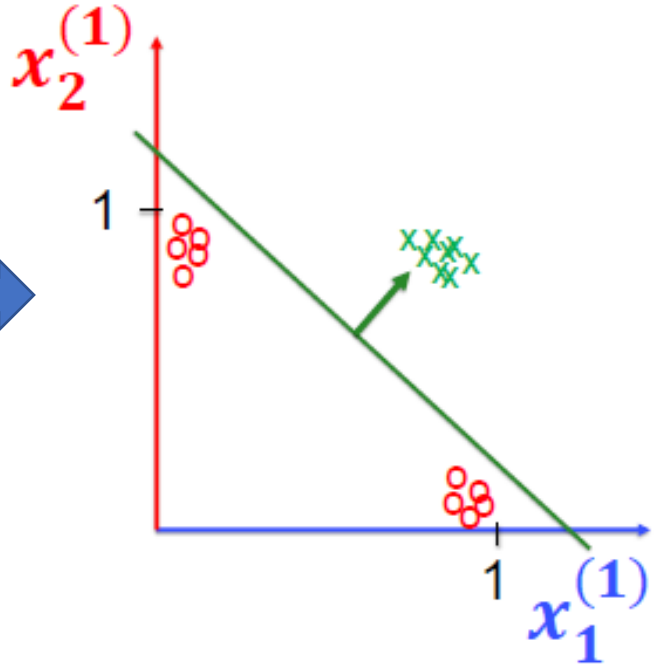


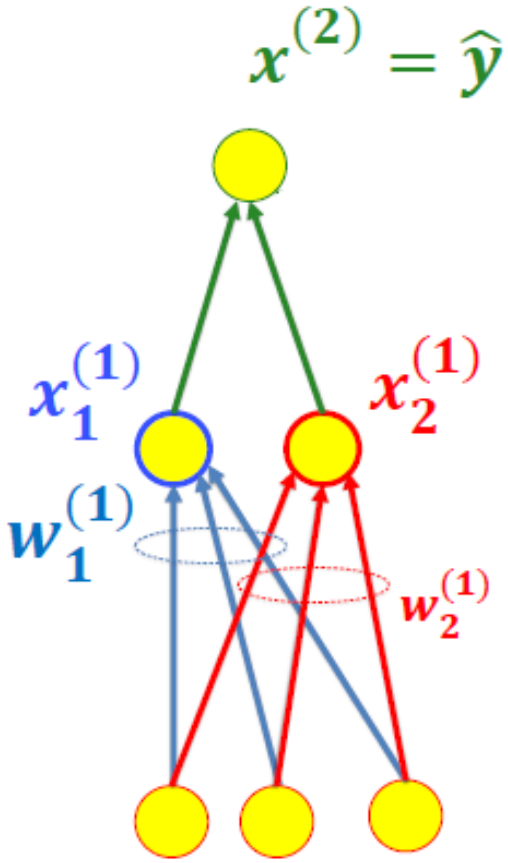


Solution: Add a second layer!

- Second layer takes as input output of red and blue neurons
- Two-layer network can solve a non-linear problem

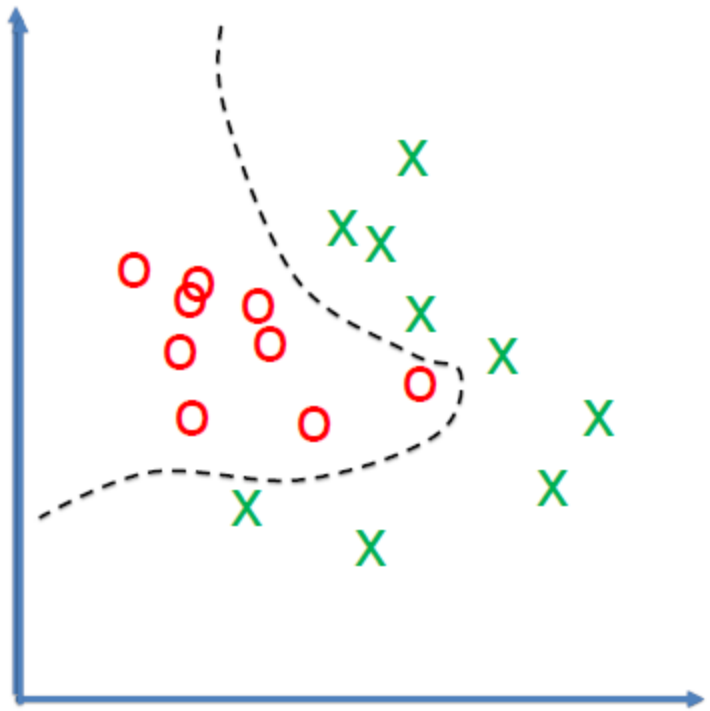






Feedforward NN: Multi Layer Perceptron (MLP)

- Neural network with more than three layer and non-linear activation function
- Very flexible, adapt to non-linear problems
- Classification and regression tasks



Universal Approximation Theorem

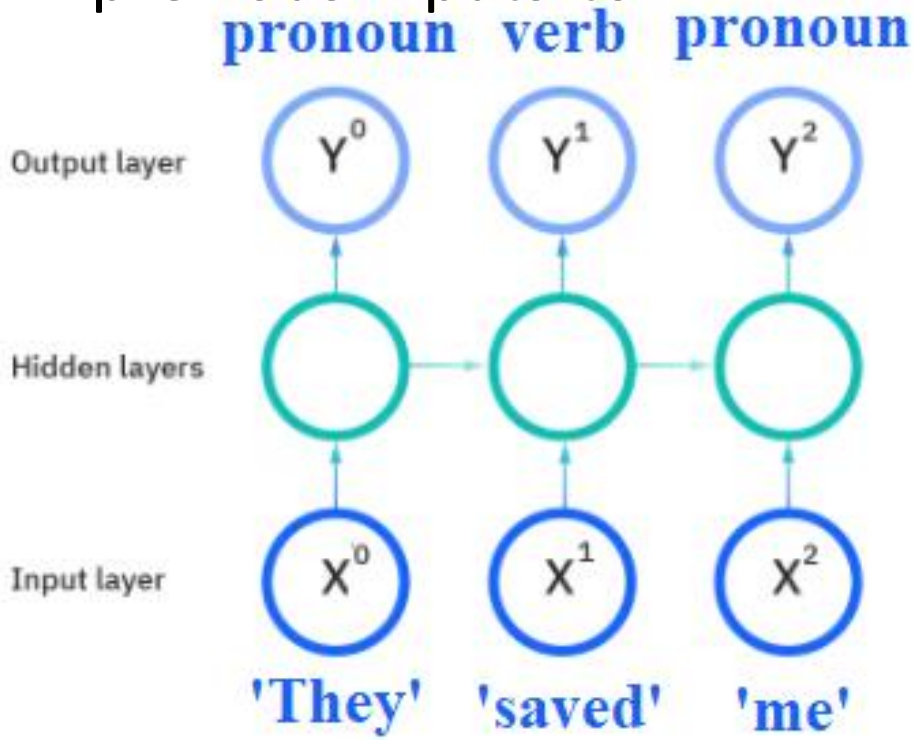
- A feedforward network with a single layer is sufficient to represent any function, but the layer may be infeasibly large and may fail to learn and generalize correctly.

  Ian Goodfellow, Deep Learning

- Big implication: a neural network can (in theory) solve any problem!

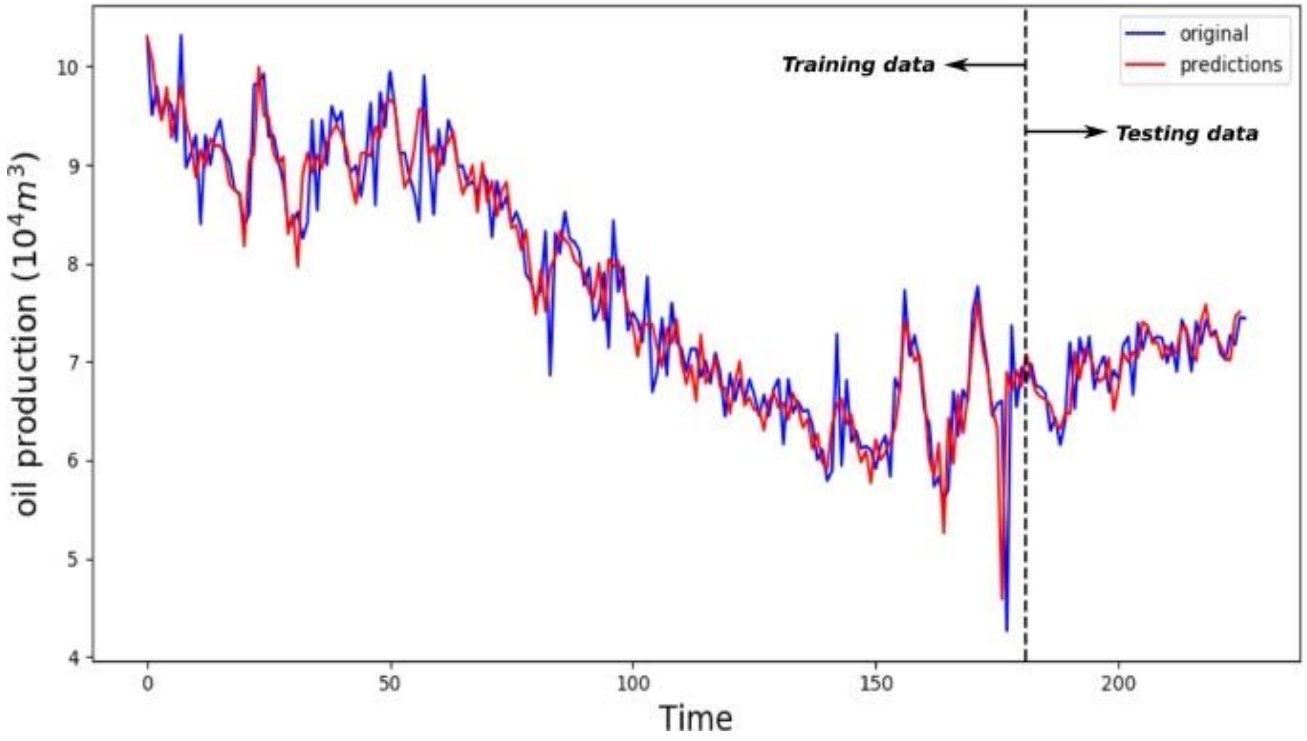
Recurrent Neural Networks: overview

- Useful to work with **sequence prediction** problems
- They have "memory": take information from previous inputs to influence current input/output
- Popular architectures:
  - LSTM (1997)
  - BRNN (1997)
  - GRUs (2014)



Recurrent Neural Networks: use cases

- Time-series prediction: stocks, productivity, weather,….



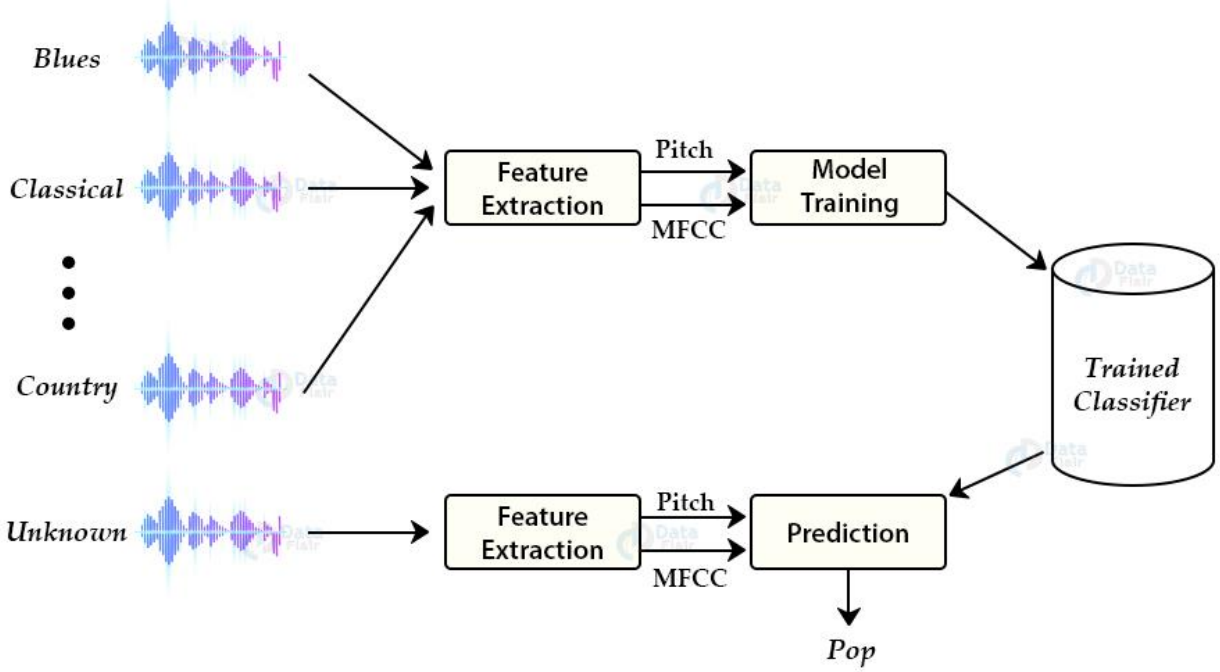
Source: Sagheer et al, 2019

Recurrent Neural Networks: use cases

- Voice detection: Siri(Apple), Alexa(Amazon), HeyGoogle(Google),…

Recurrent Neural Networks: use cases

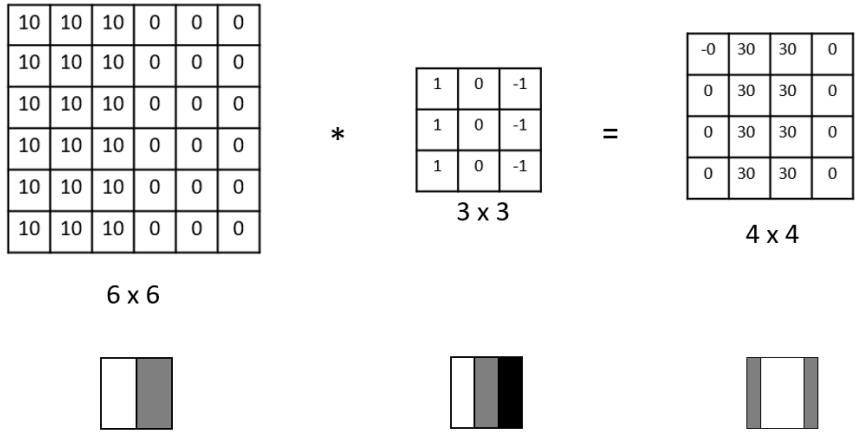
- Music generation: predict next note given a sequence of previous notes
- Music genre classifier
- Jukebox, OpenAI 2020



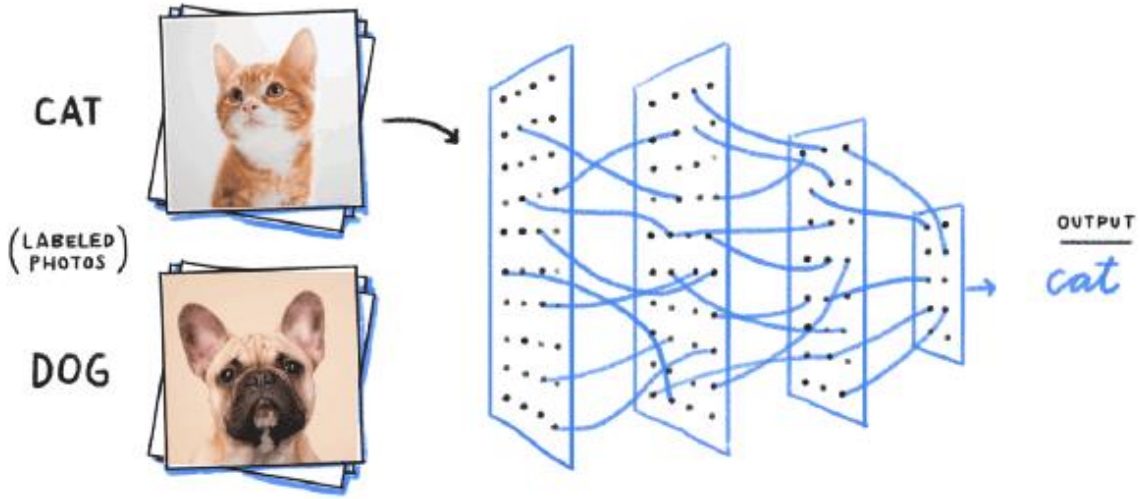
Source: DataFlair

Convolutional Neural Networks: overview

- They work really well for **image data**, they are designed to capture and learn the **spatial structure** of the data. "**Computer Vision**" tasks
- Building blocks are **filters** or kernels that extract relevant features using the **convolution** operation



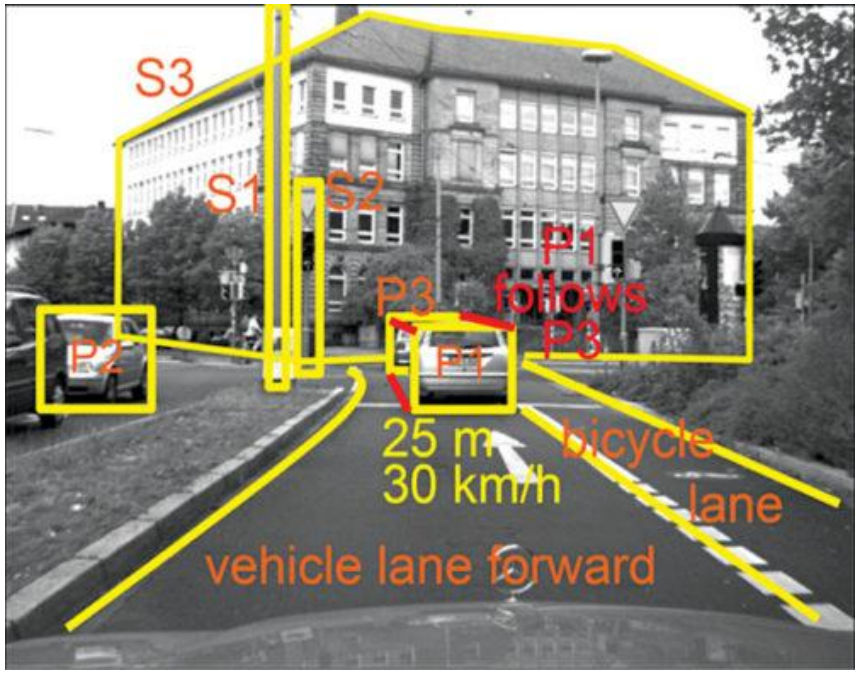
Source: datahacker



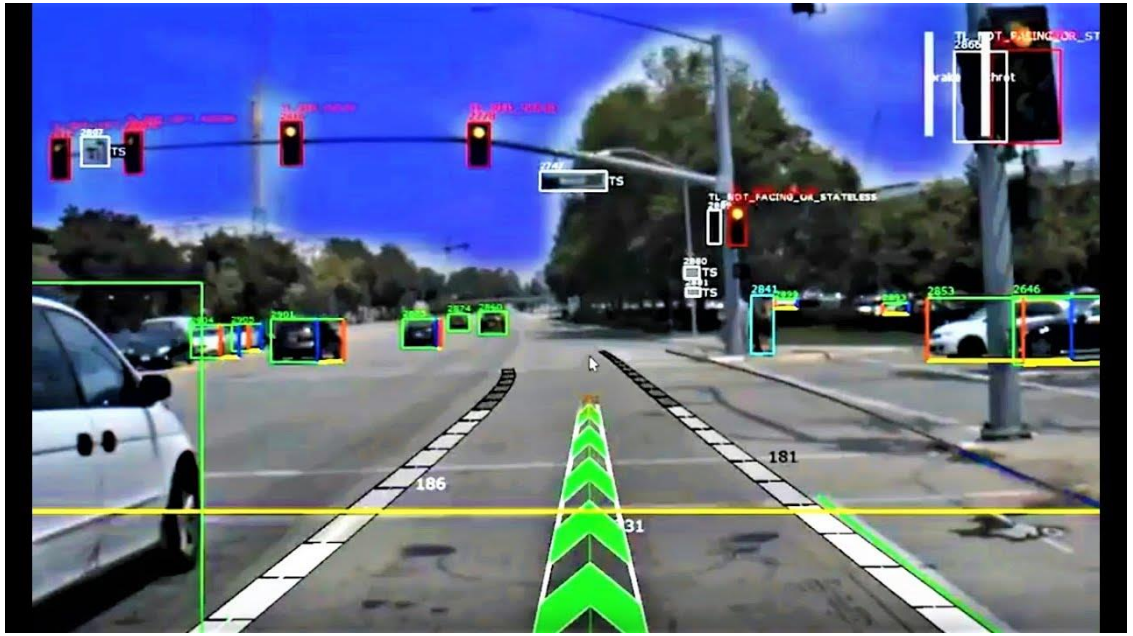
Source: analyticsvidhya

Convolutional Neural Networks: use cases

- Object and Edge detection for autonomous driving



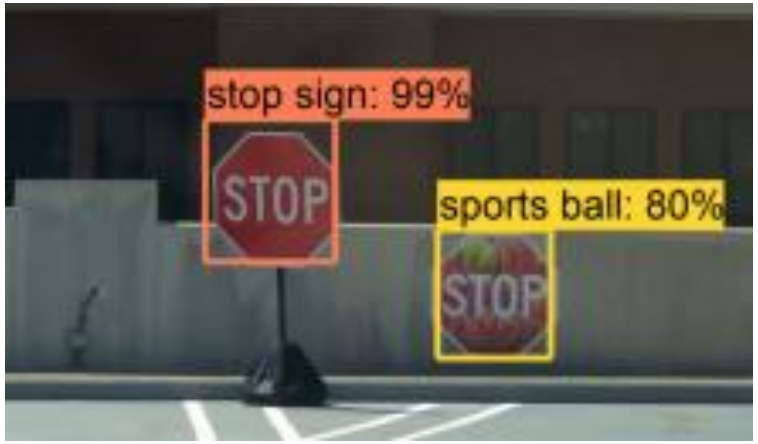
Source: *V.P. Sampath*



Source: *Vecanoi*

Convolutional Neural Networks: use cases

- Autonomous driving, not an easy problema, still a long way ahead!



Source: GeorgiaTech

The New York Times

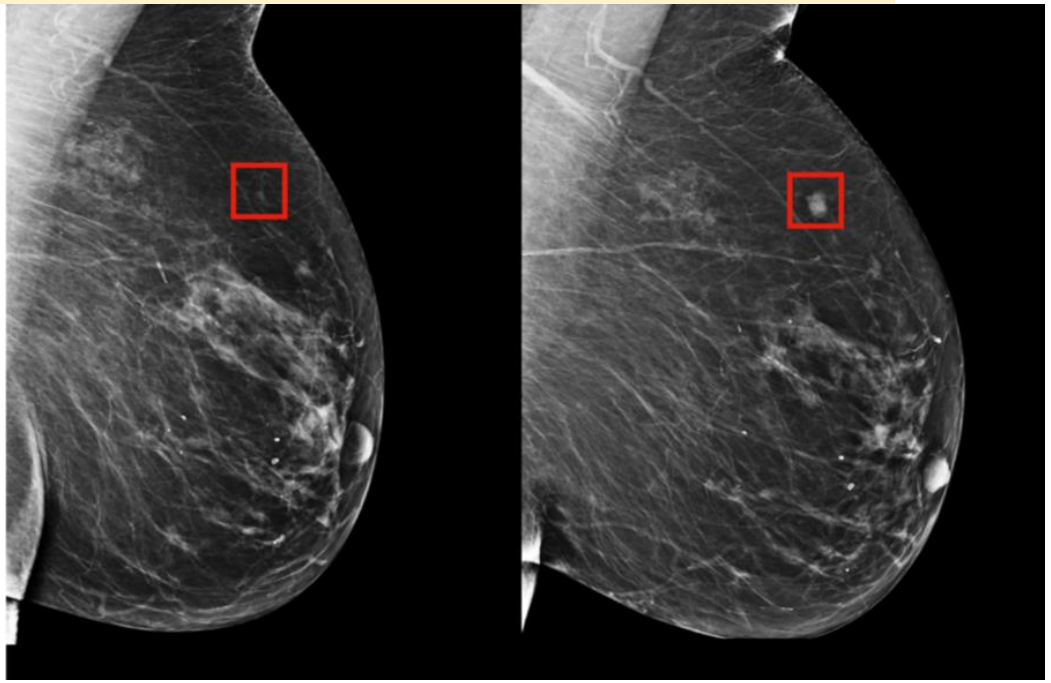
Driver Charged in Uber's Fatal 2018 Autonomous Car Crash

Elon Musk says making autonomous cars is much harder than he expected, after Tesla's timeline for the latest 'full self-driving' software slipped again

Kate Duffy Jul 6, 2021, 5:42 PM

Convolutional Neural Networks: use cases

- Several applications in healthcare: tumor detection, COVID-19 detection, …



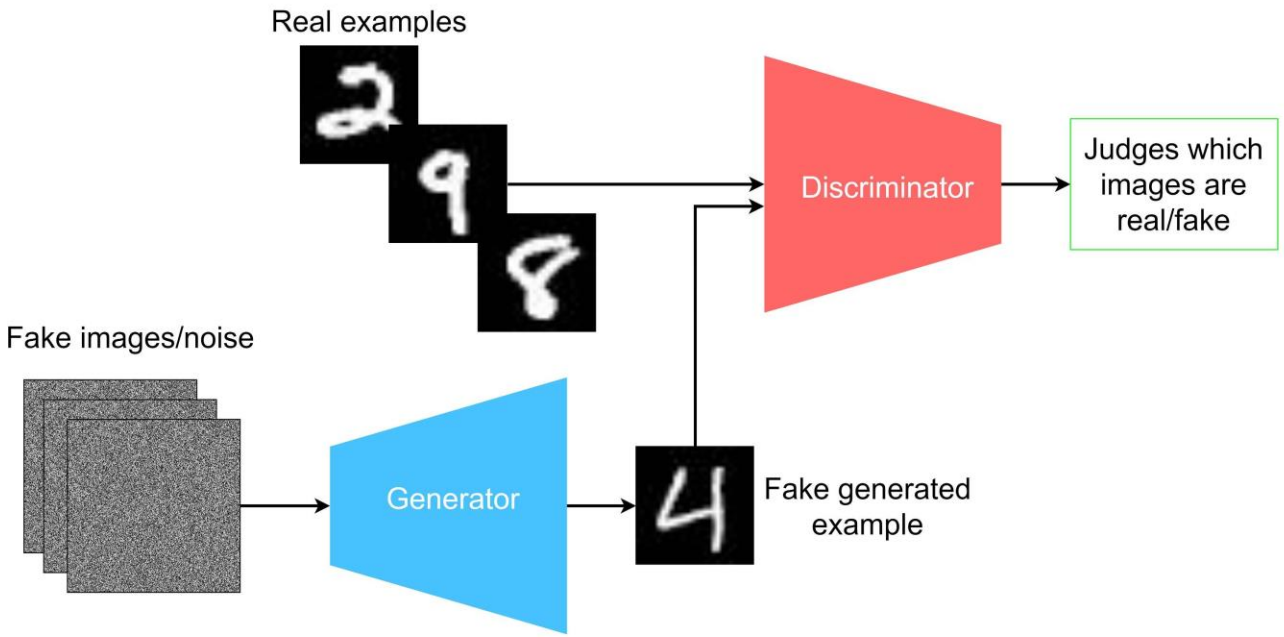
HEALTH AND SCIENCE

Google's DeepMind A.I. beats doctors in breast cancer screening trial

PUBLISHED THU, JAN 2 2020•8:13 AM EST | UPDATED THU, JAN 2 2020•8:13 AM EST

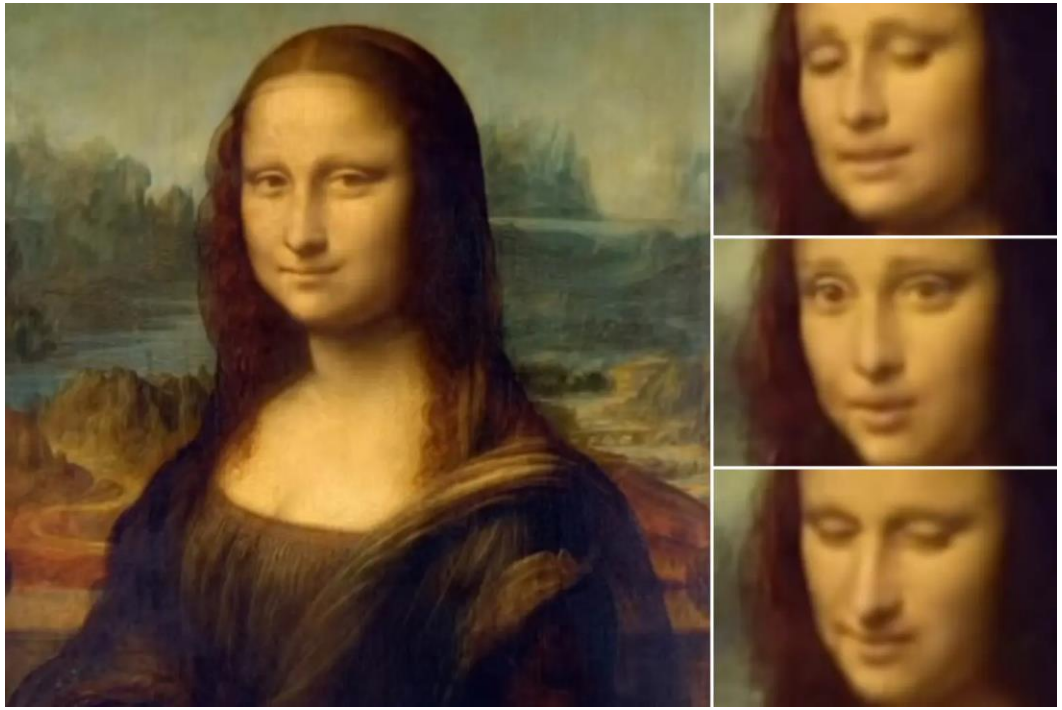
Aside: Generative Adversarial Netoworks (GANs)

- Synthetic Image/audio/video generation.
- Train a discriminator and generator modules.



GANs use cases

- Art (music, painting, …) generation
- Fashion (clothes, models, …) design

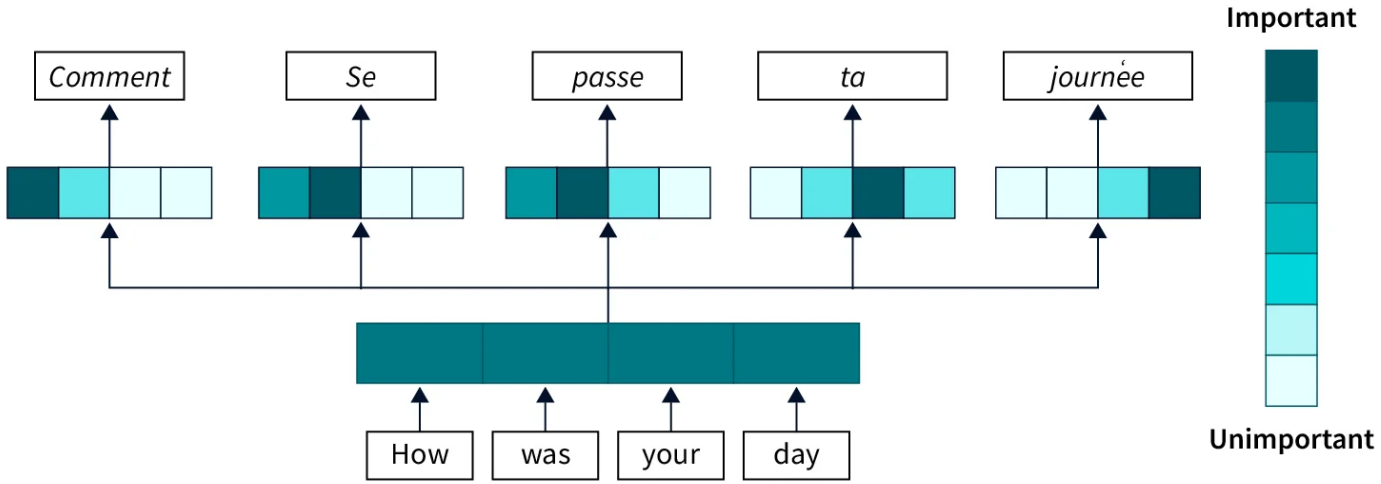


GANs risks

- Deepfakes
- Copyright issues
- …

Transformers: overview

- Most recent architecture! (*Attention is all you need,* Vaswani et al. *2017*)
- They work really well for **natural language processing tasks** (text processing, translation, ...).
- Sentences are processed as a whole (attention) rather than word by word.



Transformers: use cases

Quiz: Do you know any popular model based on transformers?

Transformers: use cases

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Transformers: use cases

- Large Language Models (ChatGPT, GPT-4, …)
- ChatGPT trained on massive amount of data + human feedback loop!

AN

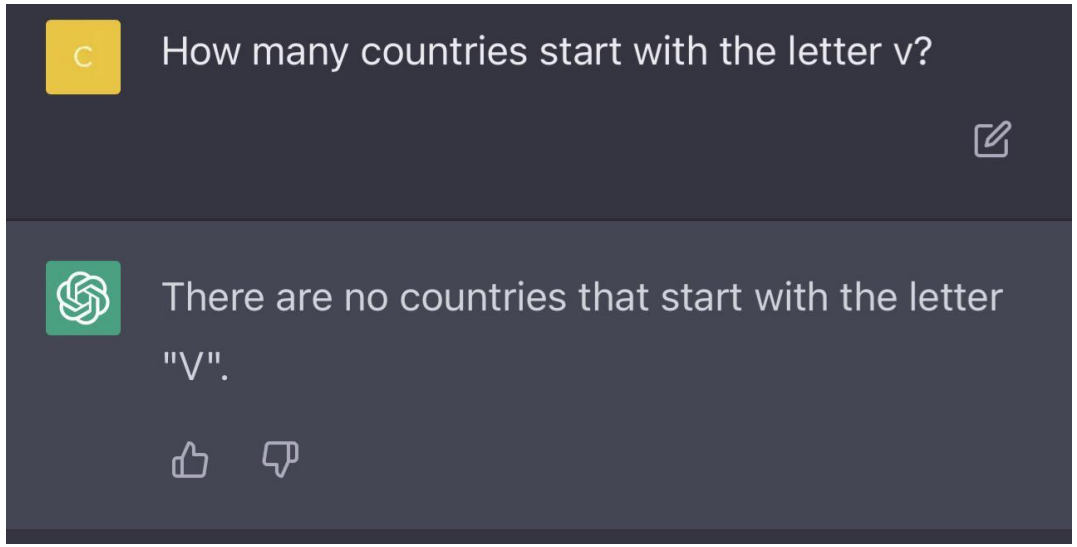
Write two sentences in french to grab the attention of 1st to 3rd year french engineering bachelor students that came to Barcelona to a Machine Learning course (and to party)

"Venez découvrir l'avenir de l'intelligence artificielle à notre cours de Machine Learning à Barcelone, alliant apprentissage et fête dans une ambiance exceptionnelle ! Rejoignez-nous pour une expérience inoubliable de fusion entre science et divertissement dans la magnifique ville de Barcelone !"

Transformers: use cases

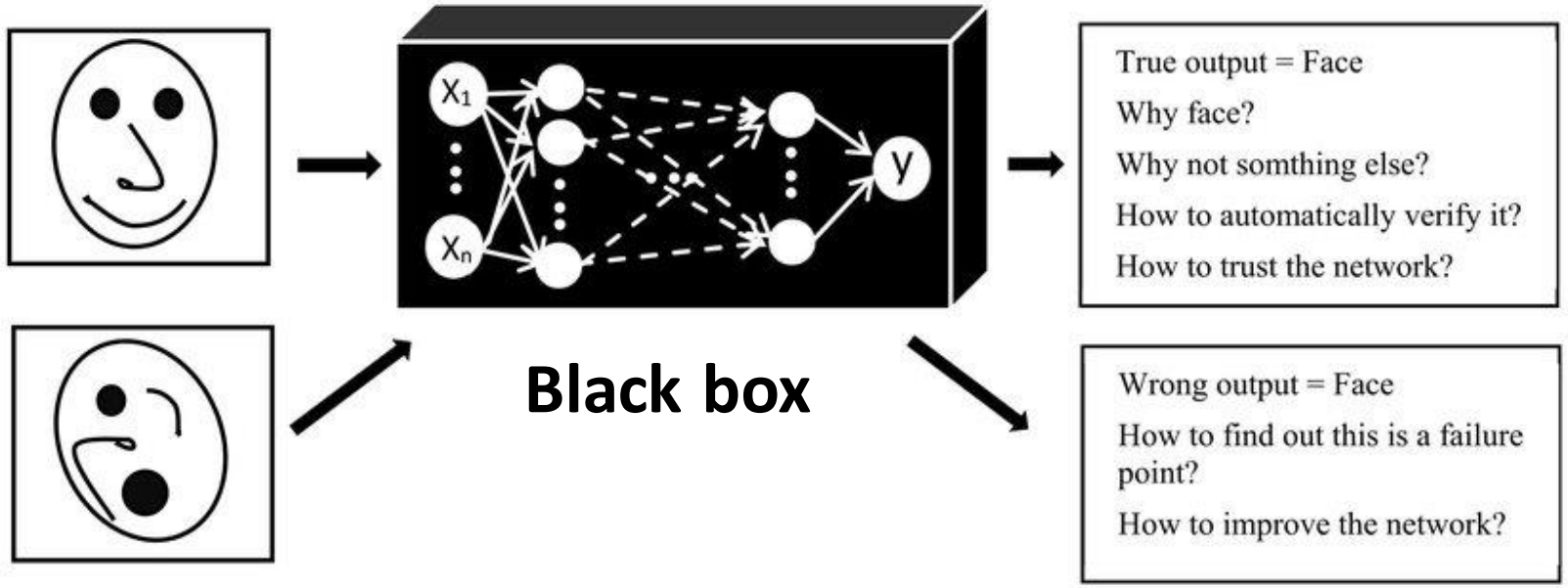
LLM are very powerful and can be really useful, but they also bring risks!

- Malicious bots
- Fake information generation
- Phishing emails
- IP & data privacy issues
- …



Deep Learning issues: interpretability

- Deep Learning models are considered “Black box” models, it is hard to understand and analyse the decisions of the model!



Source: Plataniotis et al. 2018

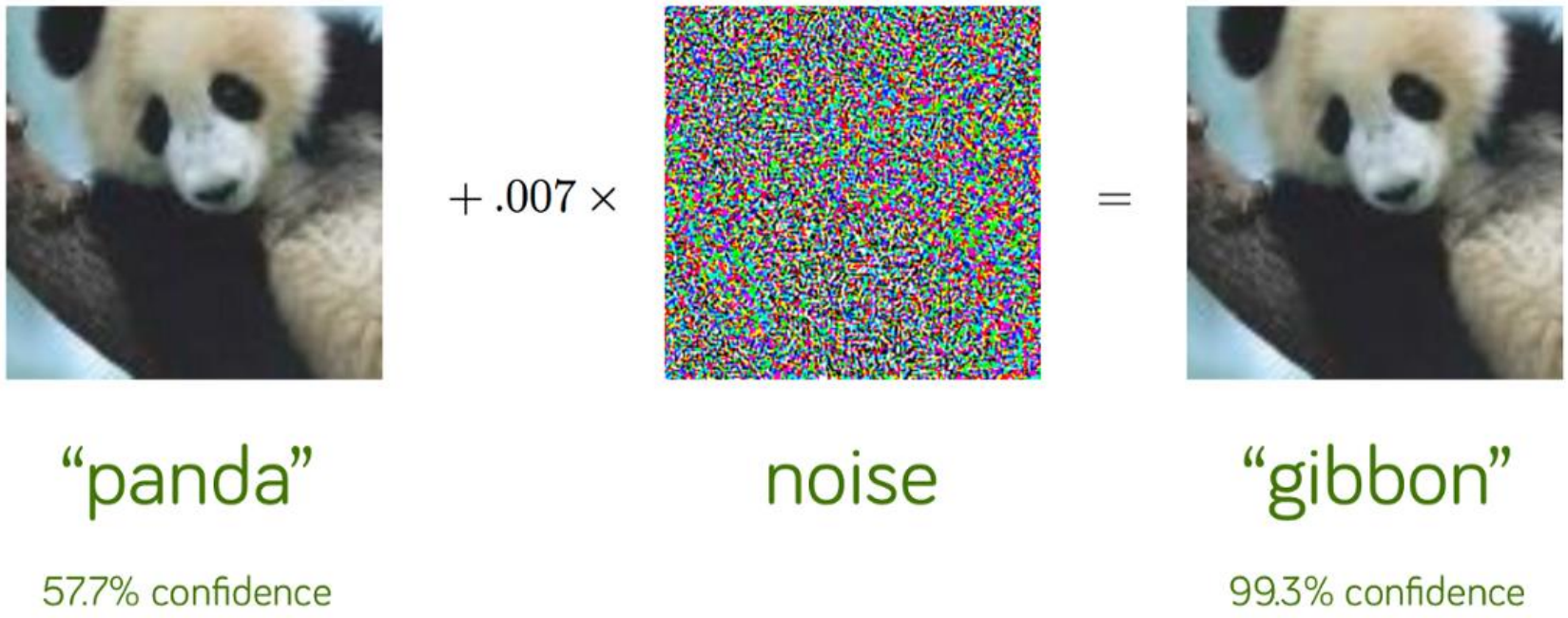
Deep Learning: pros and cons

- Pros:
  - Can execute really complex tasks, methods are flexible and adapt to different types of data
  - They can reach impressive performance

- Cons:
  - They are black-box models, not interpretable!
  - Extremely expensive to train (computational cost is huge)
  - Requires large amount of data

AI risks: adversarial attacks!

- Imperceivable noise that tricks the Deep Learning model



Source: Explaining and Harnessing Adversarial Examples, Goodfellow et al, ICLR 2015.

AI risks: adversarial attacks

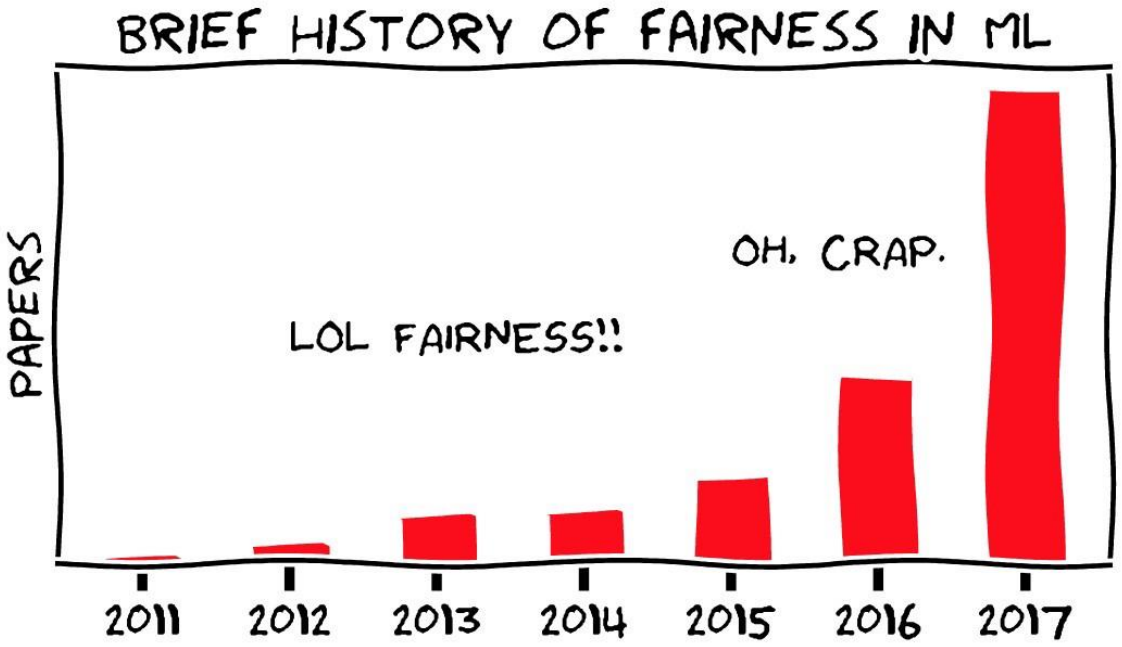
Stop Yield Speed Limit

(a) Normal (b) Attack

Source: Ben Dickson – The Daily Swig

Ethical questions around AI

- AI systems are increasingly present in high-stake decisión processes
- Is our algorithm making fair decisions? Is discriminating by race or gender?...



Source: Ziyuan Zhong

AI discrimination problem

Machine Bias

There's software used across the country to predict future criminals. And it's biased against blacks.

by Julia Angwin, Jeff Larson, Surya Mattu and Lauren Kirchner, ProPublica
May 23, 2016

AI technologies must prevent discrimination and protect diversity

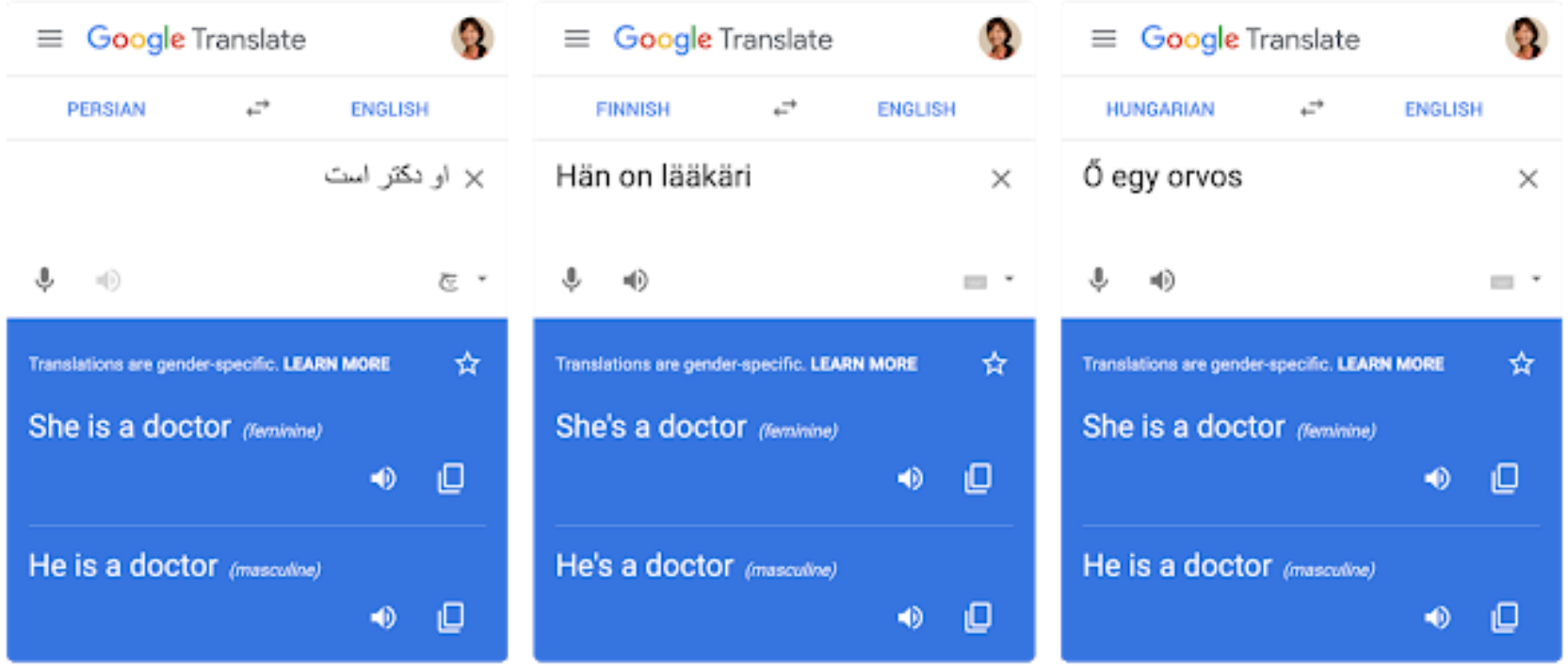
Notas de prensa CULT 16-03-2021 - 16:42

- AI technology must be trained using unbiased data sets to prevent discrimination
- Clear ethical framework needed for algorithms to protect EU's cultural and linguistic diversity
- Teachers must retain control over decisions impacting students' future opportunities

REUTERS

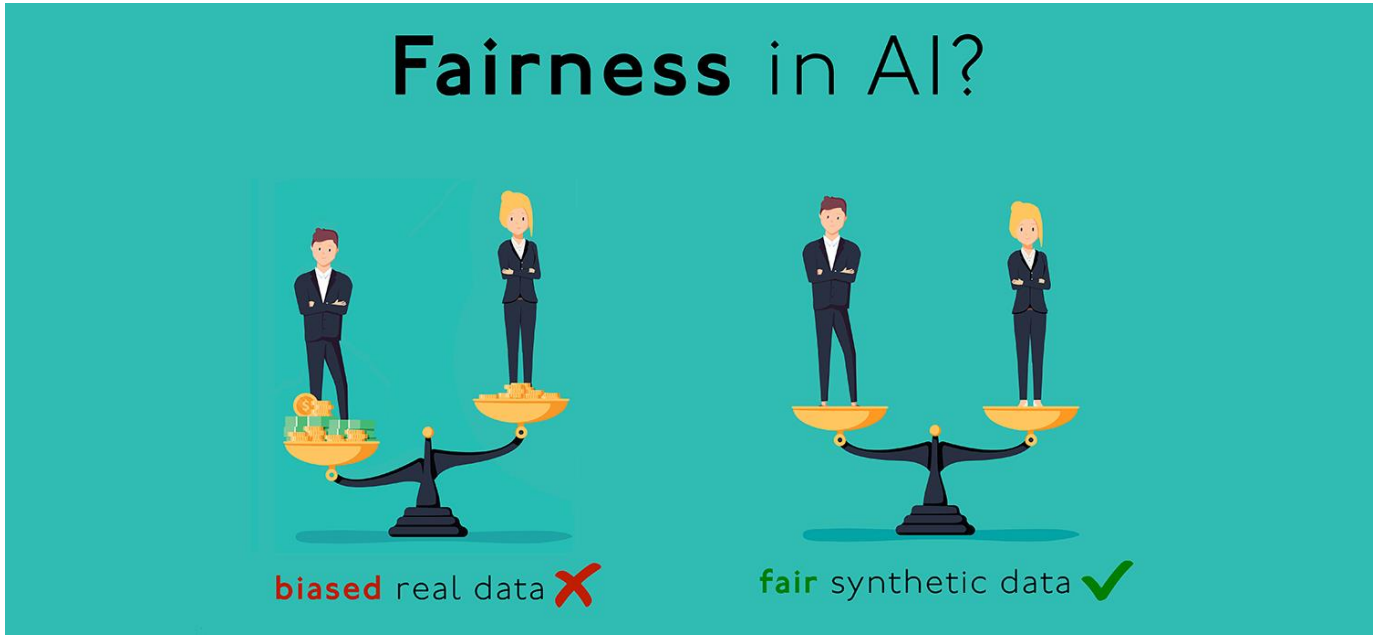
Amazon scraps secret AI recruiting tool that showed bias against women

AI discrimination problem



Real world data encodes discrimination

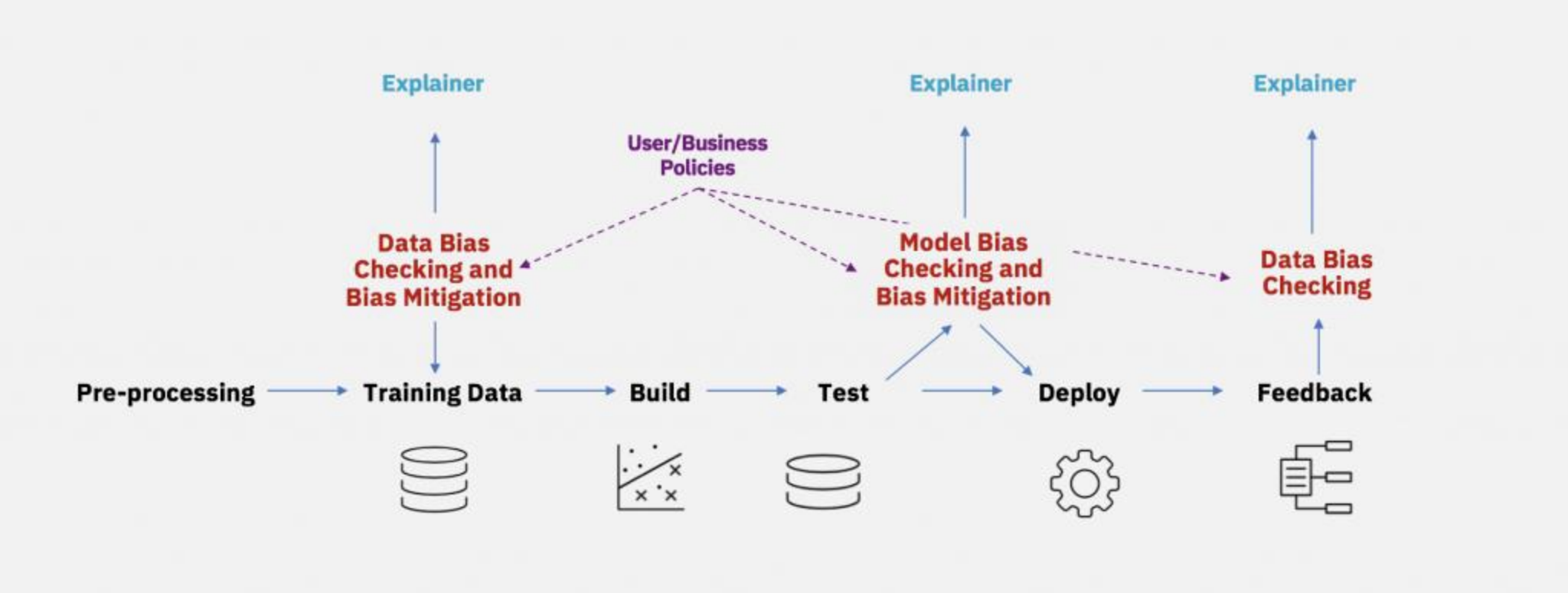
- Historical data might encode systematic discriminatory biases present in our society, such as racial, gender, or sexual orientation bias.. If we train models on such data, we créate discriminative models



Source: Mostly AI

Ensuring AI fairness

- We can mitigate data and model bias



Source: IBM