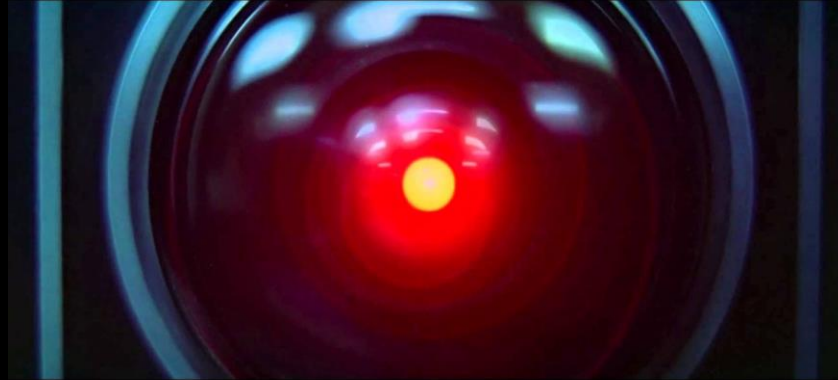


# Deep Learning Workshop

## Introduction



**Instructor:** Aaron Low

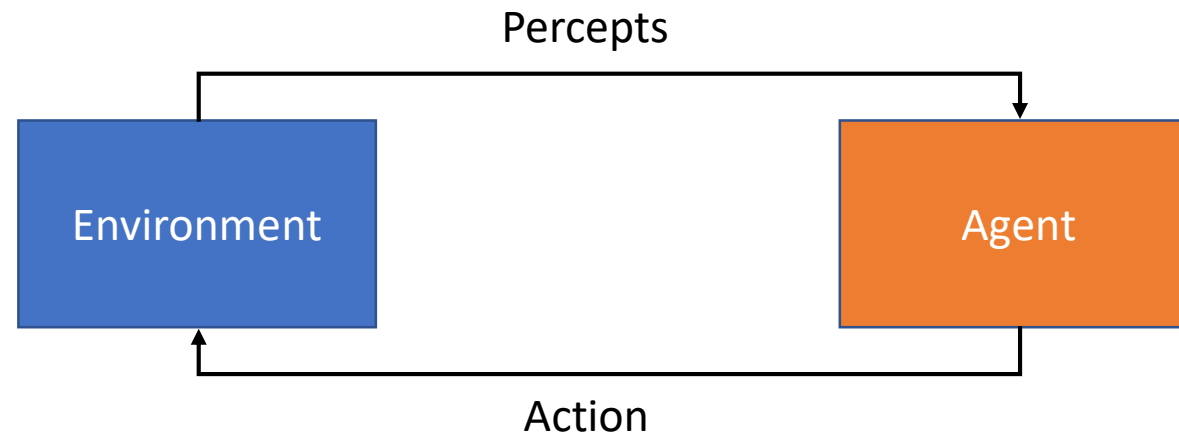
HELP University, Faculty of Computing and Digital Technology

# Workshop Overview

- Introduction to Artificial Intelligence
- What is Deep Learning?
- What is all the fuss?
- Deeper Dive into the “Black box”
- Have fun!

# What is Artificial Intelligence?

Defined as: *The study of agents that receive percepts from the environment and perform actions*<sup>1</sup>



1: Russell, S. and Norvig, P. Artificial Intelligence: A Modern Approach (3rd Edition). 2010

# Brief History of AI

- **1941:** First Program-controlled Computer
- **1943:** Neural Networks
- **1957:** Perceptron
- **1970:** Backpropagation
- **1979:** Convolutional Neural Network
- **1982:** Recurrent Neural Network
- **1989:** Reinforcement Learning
- **1997:** Deep Blue defeats world chess champion Garry Kasparov
- **2014:** Generative Adversarial Networks
- **2016:** AlphaGo beats world Go champion Lee Sedol
- **2017:** AlphaZero
- **2019:** GPT-2

\* dates are for perspective, not as definitive historical record of invention or credit

# AI in Pop Culture



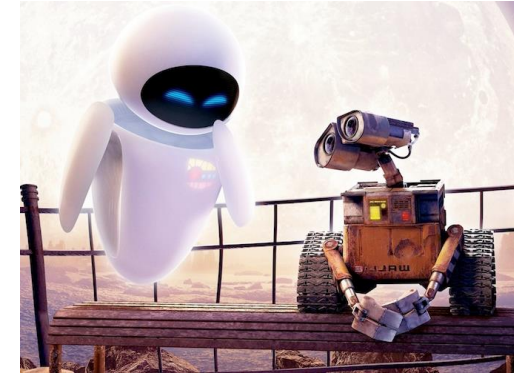
GLaDOS (Portal)



Agent Smith (Matrix)



T-800 (Terminator)



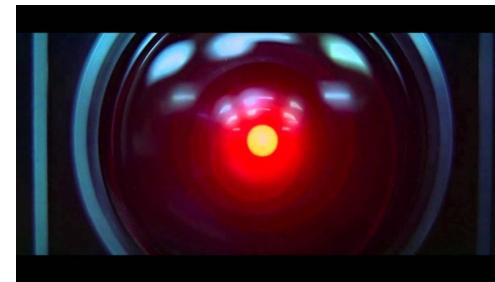
WALL-E and EVE (WALL-E)



C-3PO and R2-D2 (Star Wars)



Ava (Ex Machina)



HAL 9000 (2001: A Space Odyssey)



Ultron (Marvel)

# AI in Pop Culture



Samantha (Her)



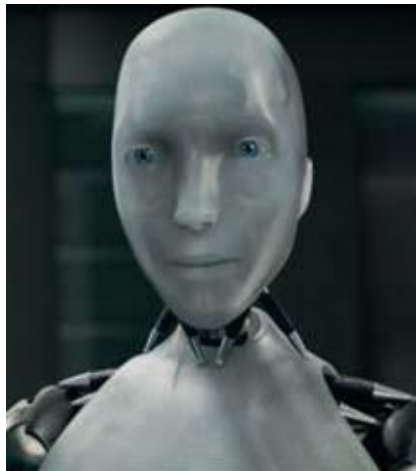
Roy Batty (Blade Runner)



David (A.I. Artificial Intelligence)



CHAPPiE (Chappie)



Sonny (I, Robot)



WOPR (WarGames)



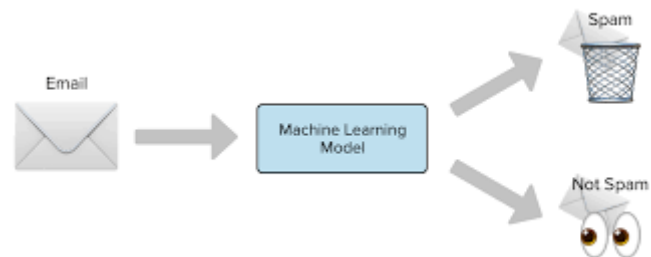
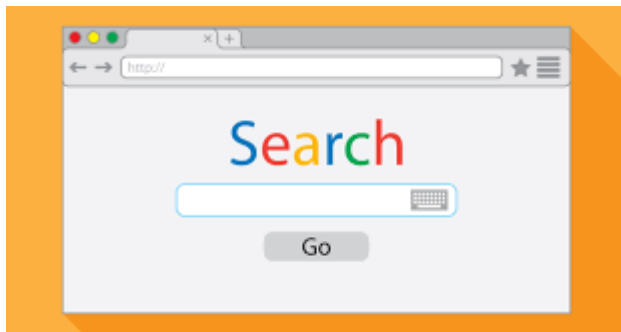
Andrew (Bicentennial Man)



Dolores (Westworld 2016)

# Why should you care about AI?

- “Artificial Intelligence is the new Electricity”<sup>1</sup>
- Artificial Intelligence is transforming industry
- It permeates most aspects of technology nowadays
  - Search engines
  - Language translation
  - Spam detection
  - Personalized marketing and advertising
- It could be **useful** to you
- It could be **harmful** to you

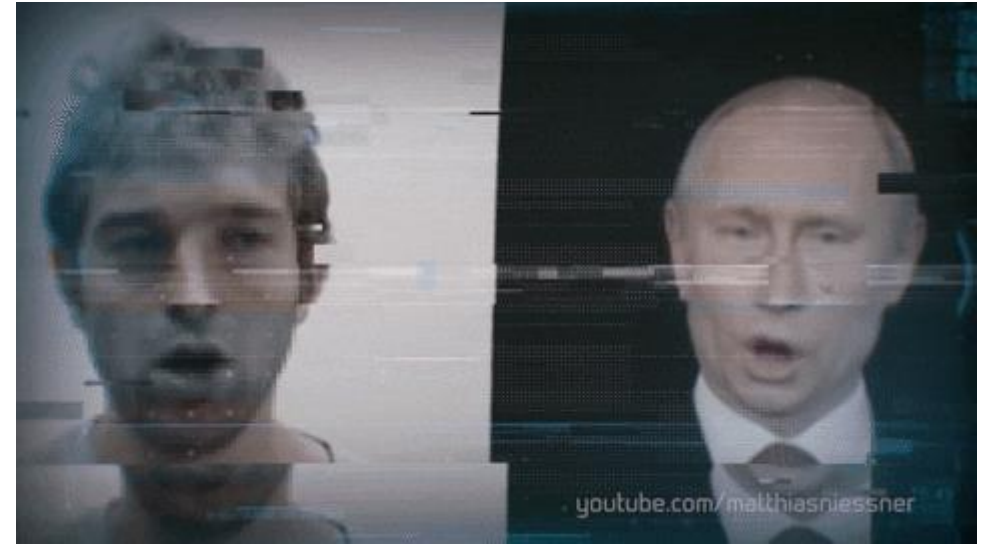


1: Andrew Ng [https://www.youtube.com/watch?v=CS4cs9xVecg&list=PLkDaE6sCZn6Ec-XTbcX1uRg2\\_u4xOEky0&index=1](https://www.youtube.com/watch?v=CS4cs9xVecg&list=PLkDaE6sCZn6Ec-XTbcX1uRg2_u4xOEky0&index=1)

2: <https://www.snopes.com/fact-check/hong-kong-protesters-projectors/>

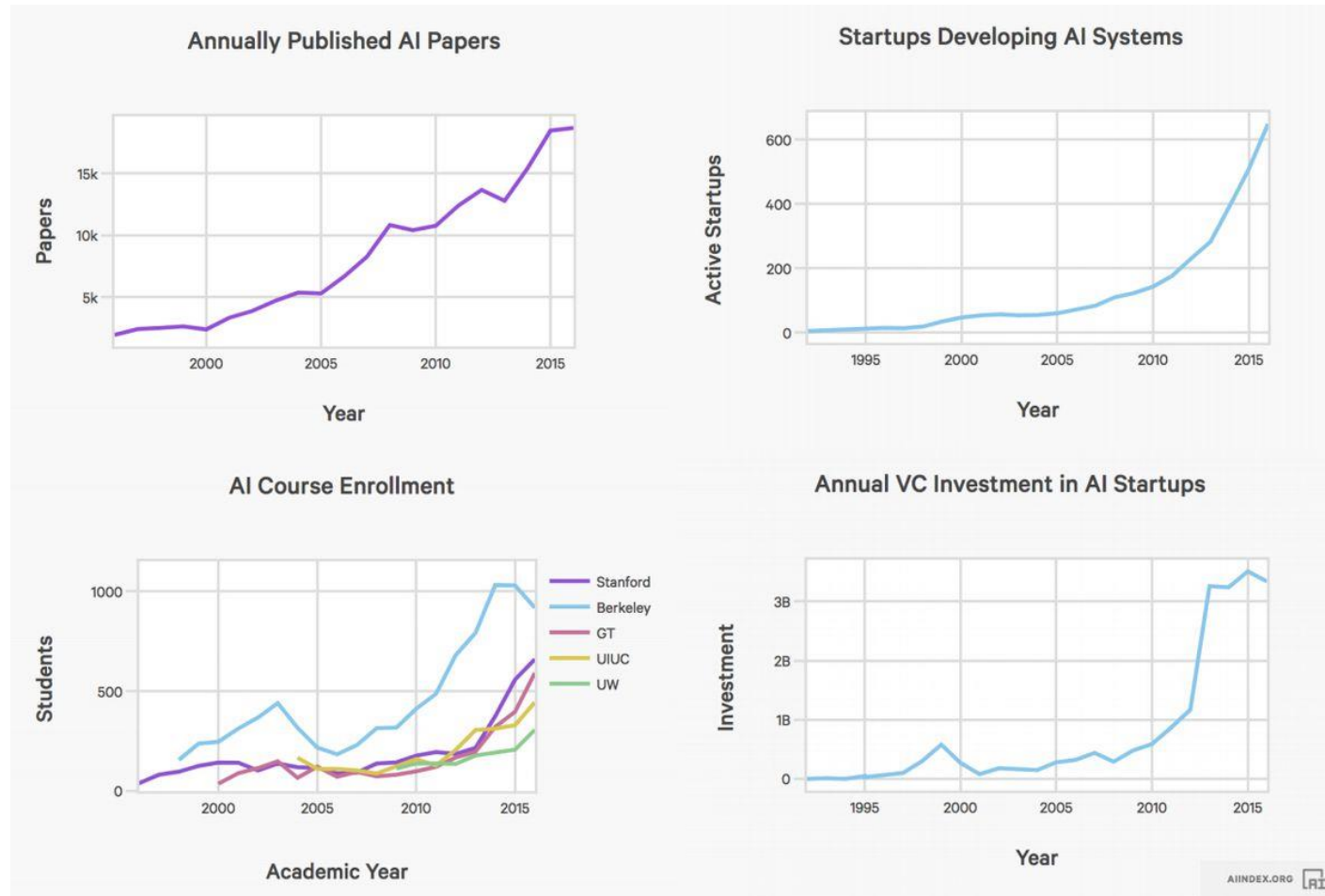


# Why should you care about AI?: DeepFake





# Why should you care about AI?



Graphs from <https://www.forbes.com/sites/louiscolombus/2018/01/12/10-charts-that-will-change-your-perspective-on-artificial-intelligences-growth/#94ee80e47583>

# Be careful what you read about AI

- **AI snake oil<sup>1</sup>**
  - Obfuscation of facts
  - Overselling what AI can do
  - There is a lot of commercial interest in AI these days
  - Sometimes it's too good to be true
  - Sometimes it can be done easily with simpler methods
- **AI Hype<sup>2</sup>**
  - The term 'AI' is thrown around very loosely
  - Sometimes it's not totally autonomous; humans still play an important role
  - There is always some sort of limitation

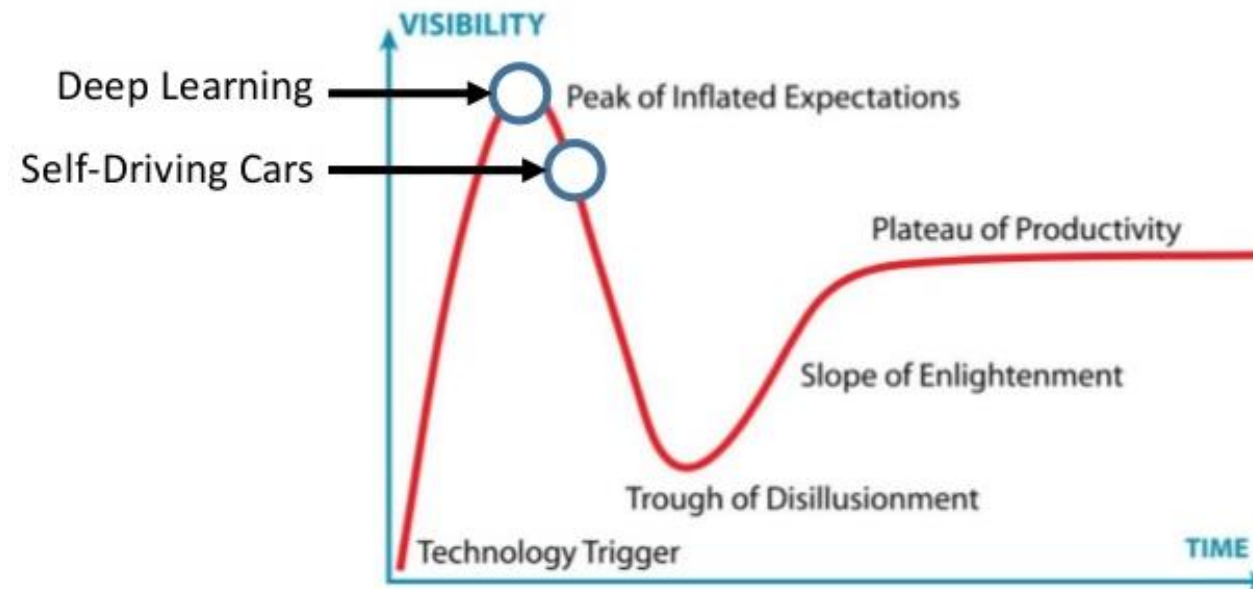
**Think critically**

1: <https://www.cs.princeton.edu/~arvindn/talks/MIT-STS-AI-snakeoil.pdf>

2: <https://www.skynettoday.com/editorials/ai-coverage-best-practices>

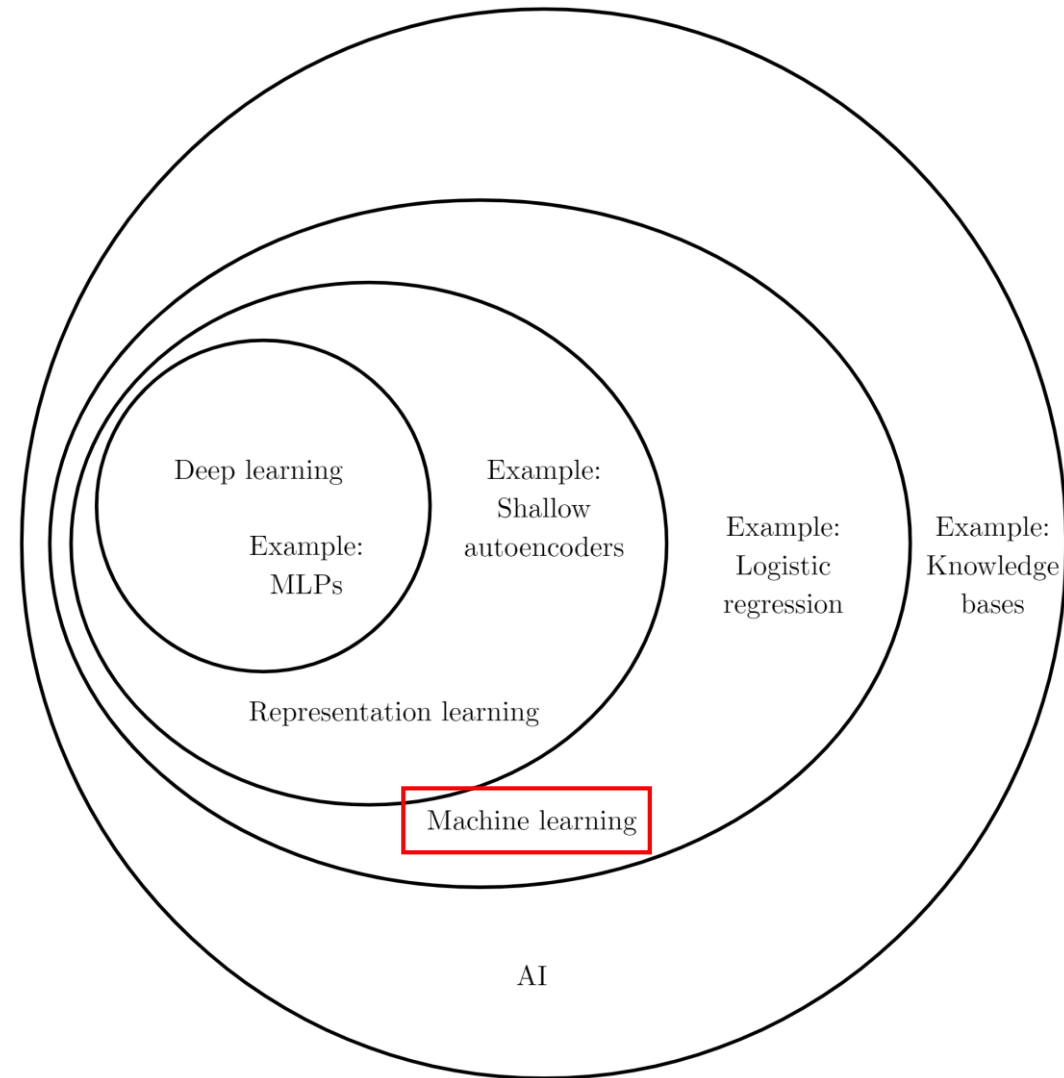
# Be careful what you read about AI

## Gartner Hype Cycle<sup>1</sup>



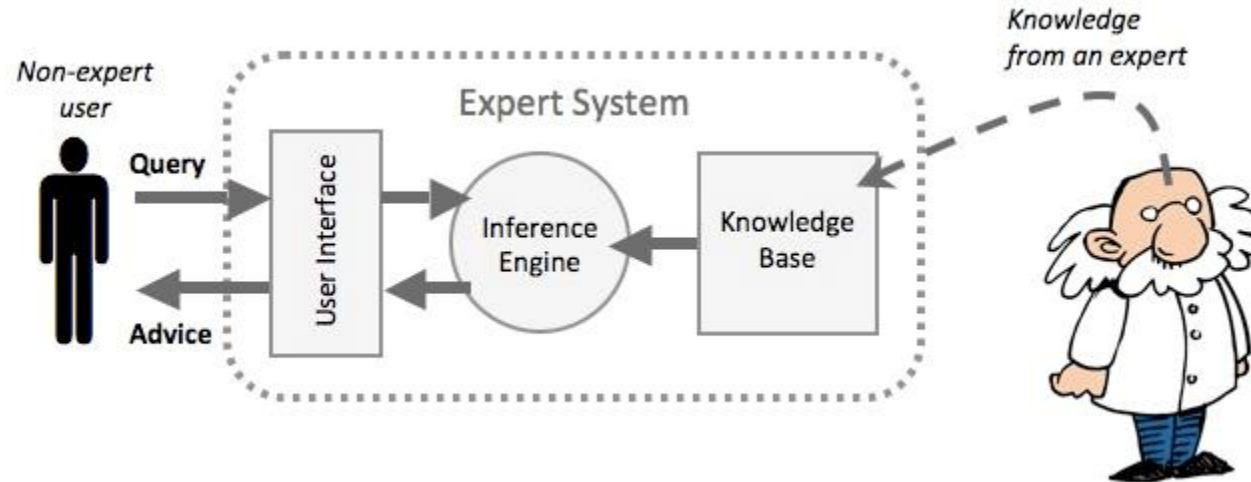
1: MIT Deep Learning Basics: Introduction and Overview Lex Fridman <https://www.youtube.com/watch?v=O5xeyoRL95U>

# Machine Learning and Artificial Intelligence

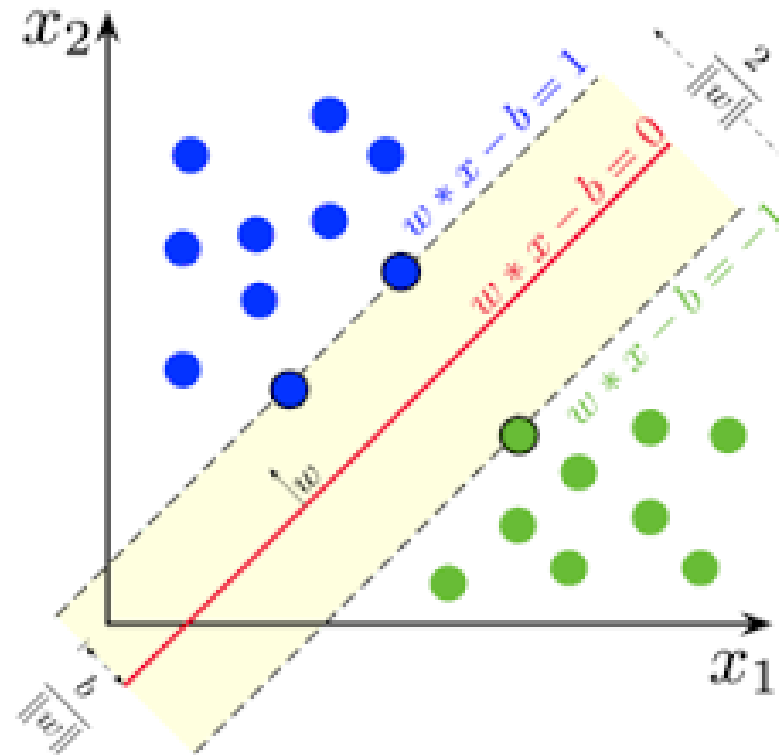


# “Classical” AI: Expert Systems

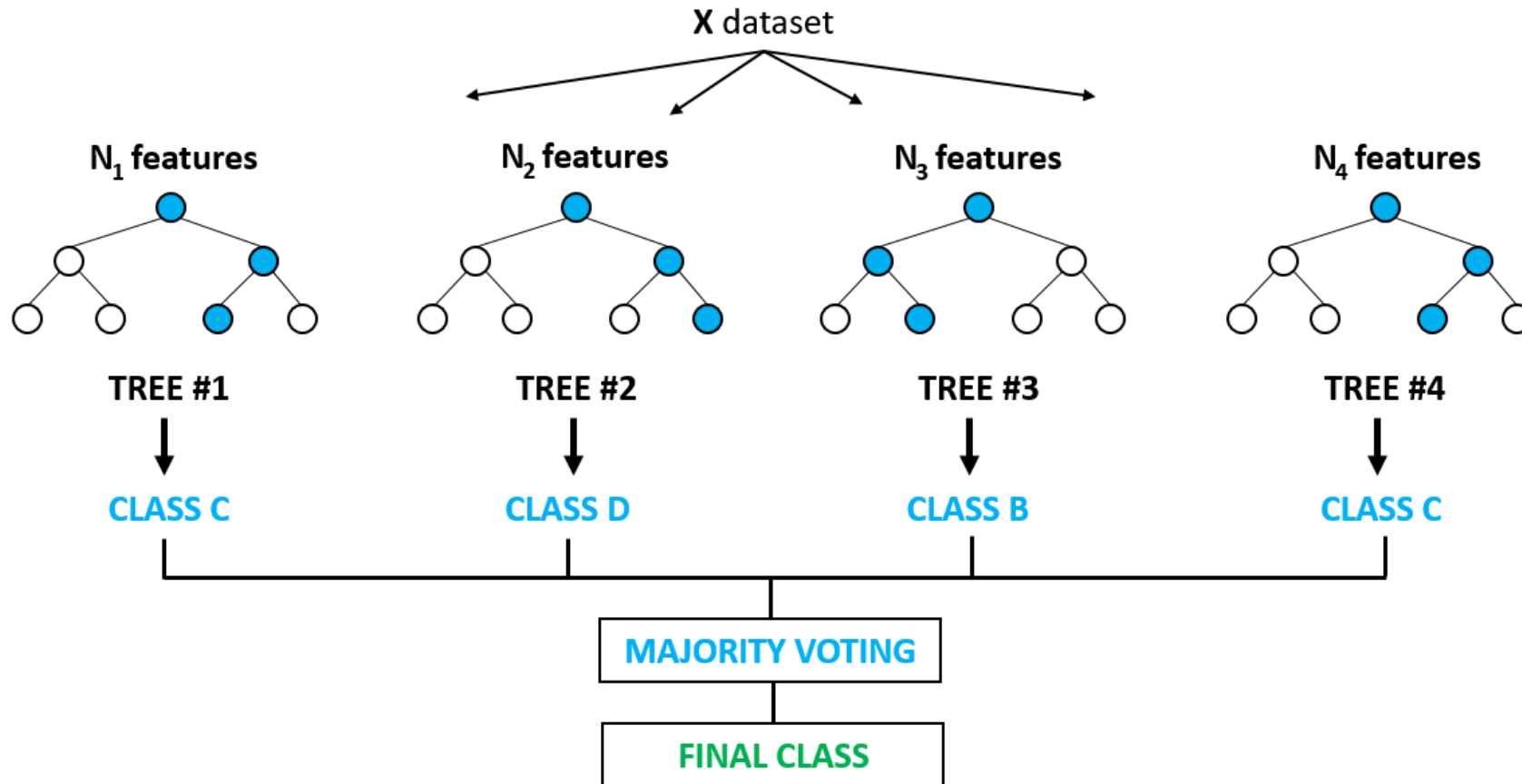
The knowledge base is created from **information** provided by **human experts**



# “Traditional” Machine Learning: Support Vector Machines



# “Traditional” Machine Learning: Random Decision Forest

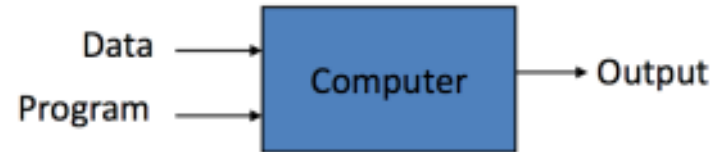




# What is Machine Learning?

**Defined as:** *The science of getting computers to learn and act like humans do, and improve their learning over time in autonomous fashion, by feeding them data and information in the form of observations and real-world interactions<sup>1</sup>*

## Traditional Programming



## Machine Learning

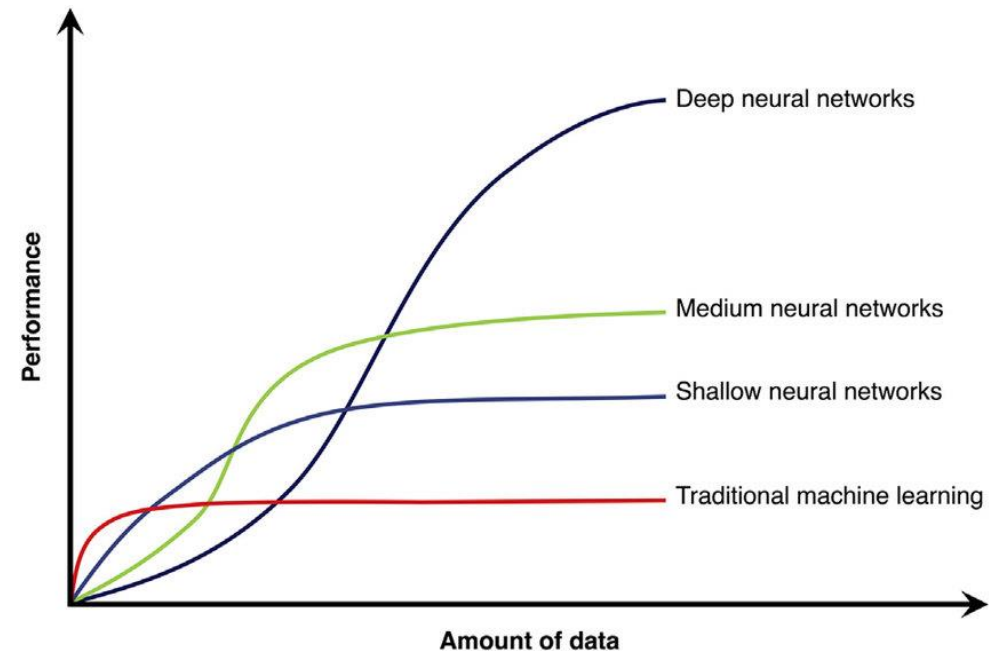


**Deep Learning** is a subclass of machine learning which involves the usage of multiple layers of **neural networks**

1: <https://emerj.com/ai-glossary-terms/what-is-machine-learning/>

# Why Deep Learning?

- **Reduce time spent programming**
  - Hand coded rules are mostly unnecessary
- **Customize and scale products**
  - Only need to collect data for new market
- **Solve seemingly “unprogrammable” tasks**
  - Face recognition and classification
  - Human pose estimation
  - Beat the world’s best player at Go
- **Improvement in computational speed**
  - Better hardware (GPUs)
  - Data parallelism
- **Increase in quantity of data**
  - Web services
  - Mobile apps
  - Research and industry



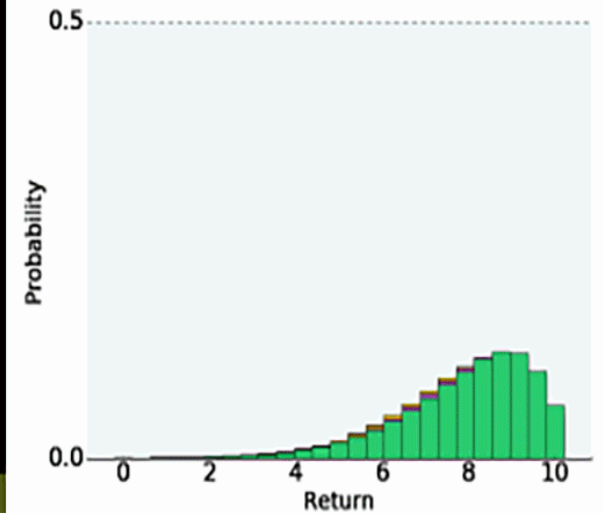
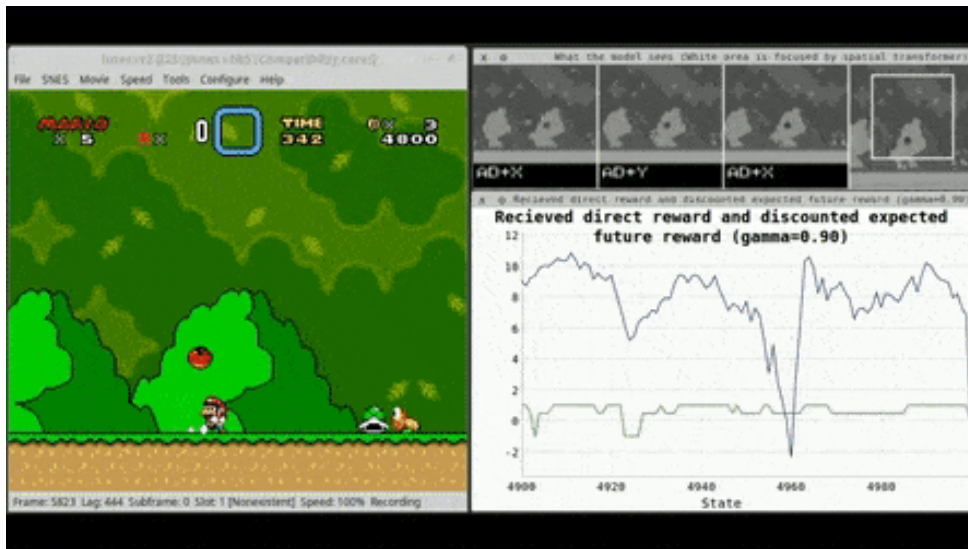
# Broad Goals

- **Automation**
  - Reduce tedious human labour
  - Improve efficiency
  - e.g. Algorithm trading, Automatic spam mail detection, Self-driving cars
- **Solve problems**
  - Solve problems too complex or tedious for humans to solve in a direct manner
  - Discovery of useful features in complex data
  - e.g. Translate English to Chinese, Facial detection
- **Simulation and Modelling**
  - Create models that can accurately predict future events
  - e.g. Weather prediction, Stock market prediction
- **Improved tools**
  - Tools that can provide advice with increased precision and rigour
  - Tools that can reduce risk in dangerous situations
  - e.g. Computer-aided interpretation of medical images, Disaster relief robots



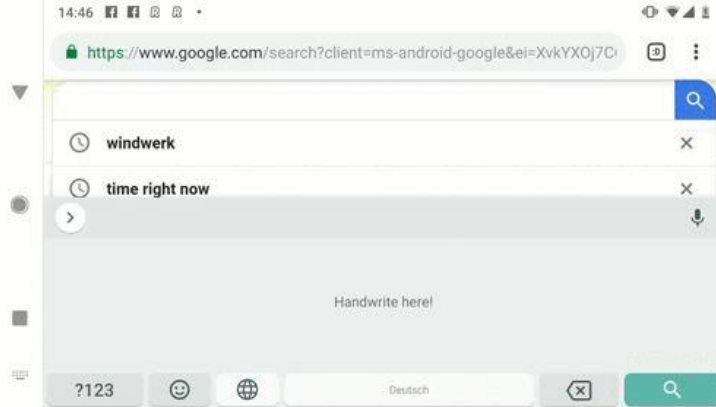


# What can Deep Learning do?: Game Playing

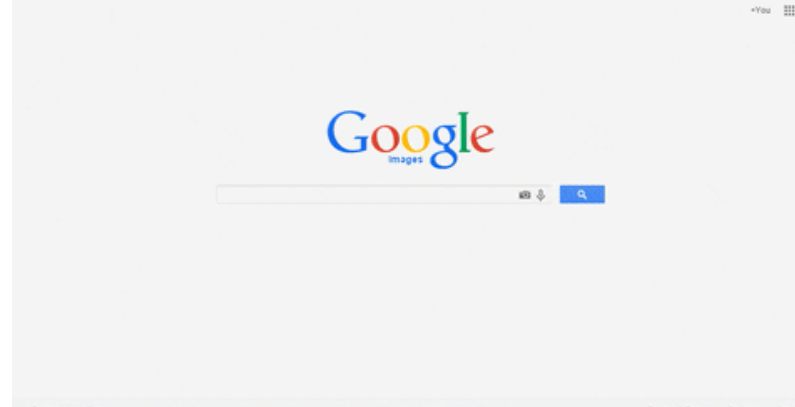




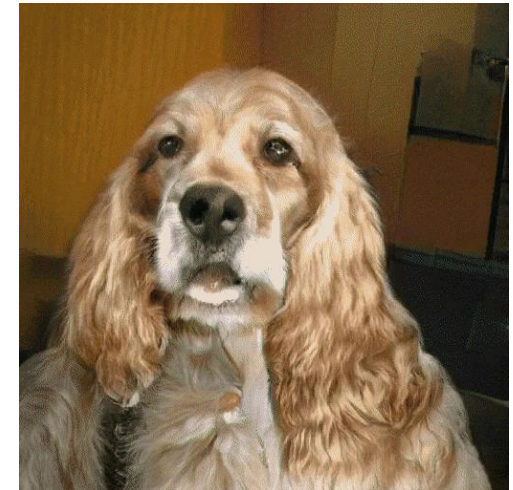
# What can Deep Learning do?: Many More!



Handwriting Transcription



Search by Image



Generate fake images

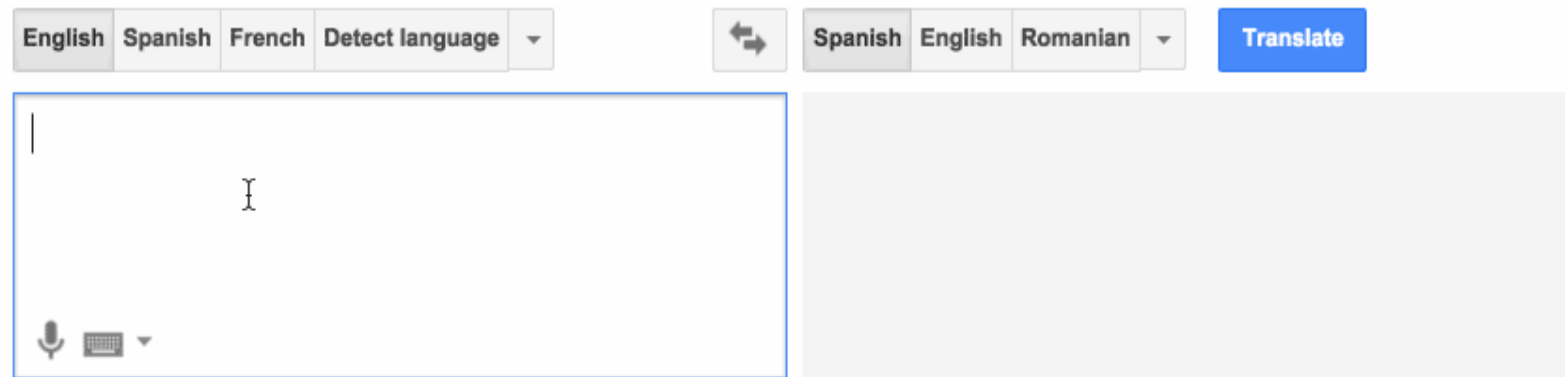
# What can Deep Learning do?: Many More!



AlphaGo beats Lee Sedol (2016)



Self-driving car (Tesla)



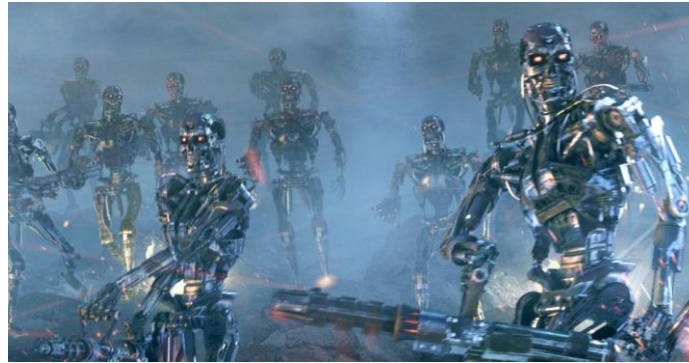
Machine Translation



# What CAN'T Deep Learning do? (as of 2019)



Love



World domination



Tell intentionally funny jokes



Beat humans at debate<sup>1</sup>  
(IBM Project Debater)



Make ethical decisions



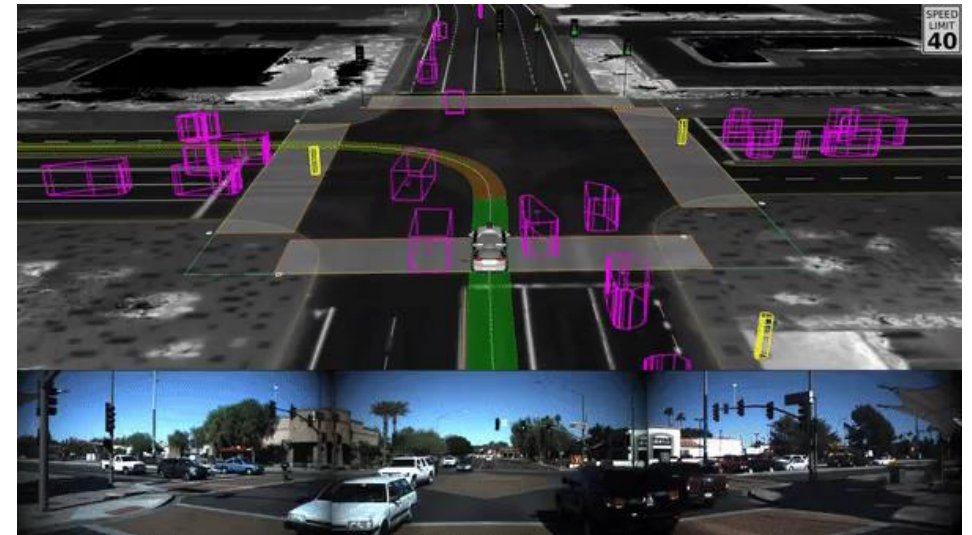
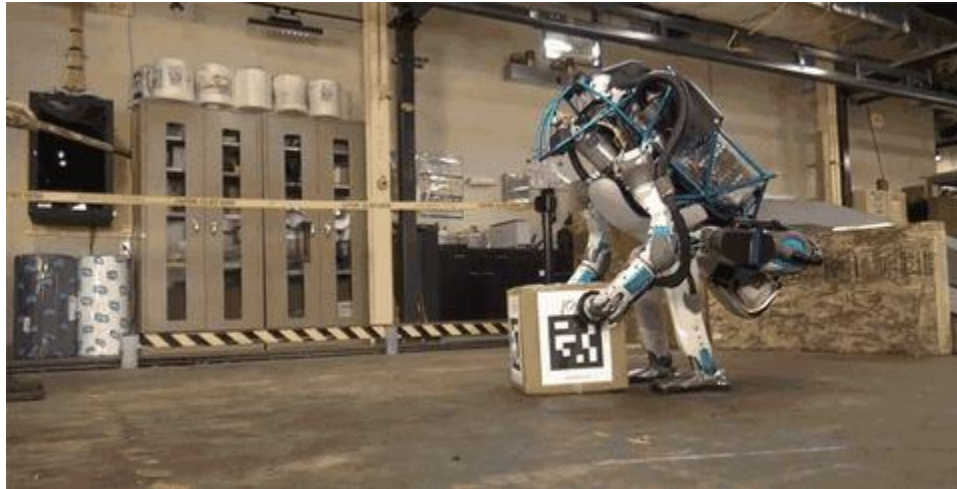
Save the environment<sup>2</sup> (?)

1: <https://edition.cnn.com/2019/11/21/tech/ai-cambridge-university-debate/index.html>

2: <https://www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/>

# What ISN'T Deep Learning?

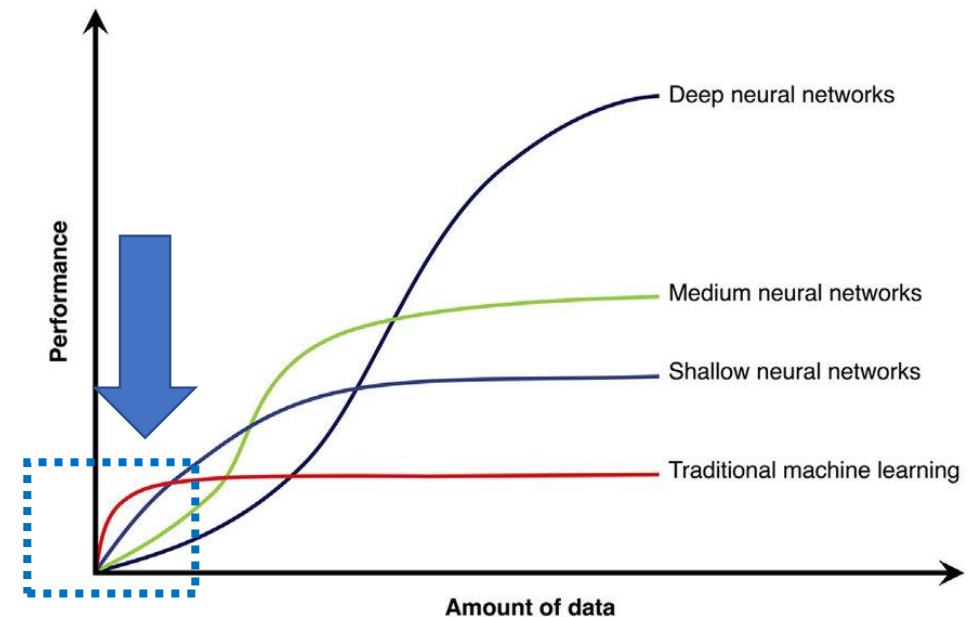
- Deep Learning is **not** necessarily used in certain real world applications
- **Not all** autonomous systems, robotics are entirely reliant on Deep Learning
- Efforts are being made to improve existing applications with Deep Learning



# When to use Deep Learning?

(Rules of thumb) <sup>1</sup>

- **When you have a lot of data**
- **When you have unstructured data**<sup>2</sup>
  - e.g. audio signals, images, text
- **Supervised learning**<sup>3</sup>
  - This is where AI is most lucrative
- **Reinforcement learning**
  - Great success has been shown in playing games



Sometimes using classical methods can yield similar or better results

1: Deep Learning is currently in very active research so you can still use it for other problems but there's no guarantee it will be better than classical methods

2: Structured data works well with both deep learning and classical methods whereas unstructured generally works better with deep learning

3: Unsupervised/Semi-supervised learning has shown success in research but not commercial as far as I know

# Are Humans Obsolete?

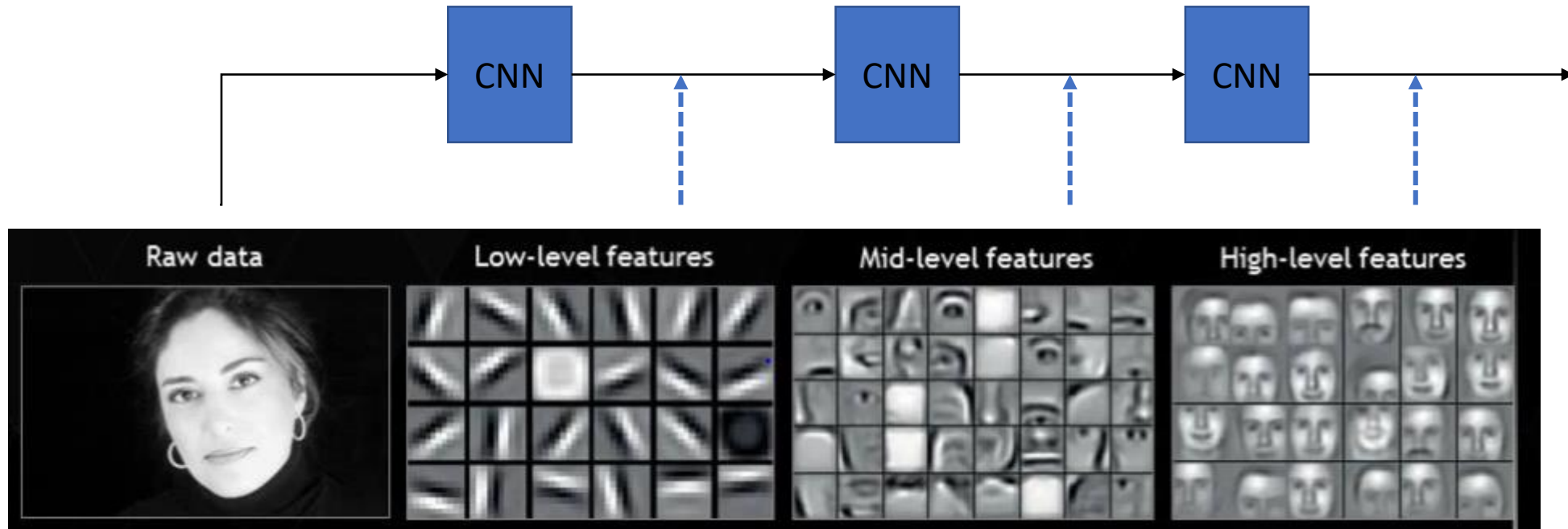
- Certain factors in Deep Learning can sometimes lead to **unintended consequences**<sup>1</sup>
- Humans are still necessary to ensure the safety and functionality of AI systems



1: MIT Deep Learning Basics: Introduction and Overview Lex Fridman <https://www.youtube.com/watch?v=O5xeyoRL95U>

# Deep Learning Intuition

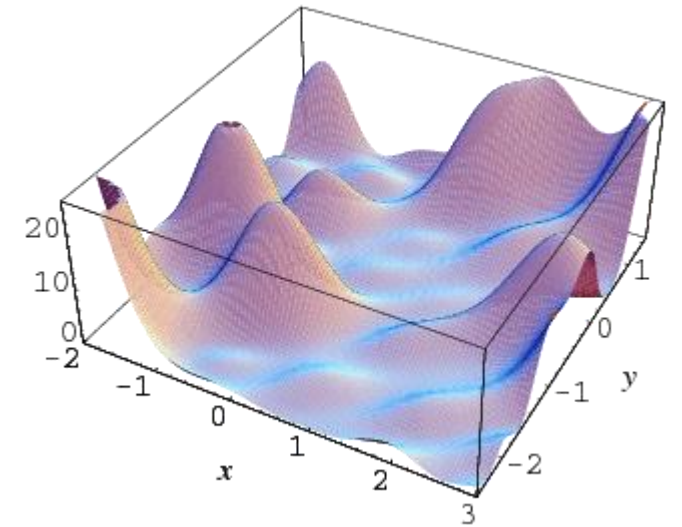
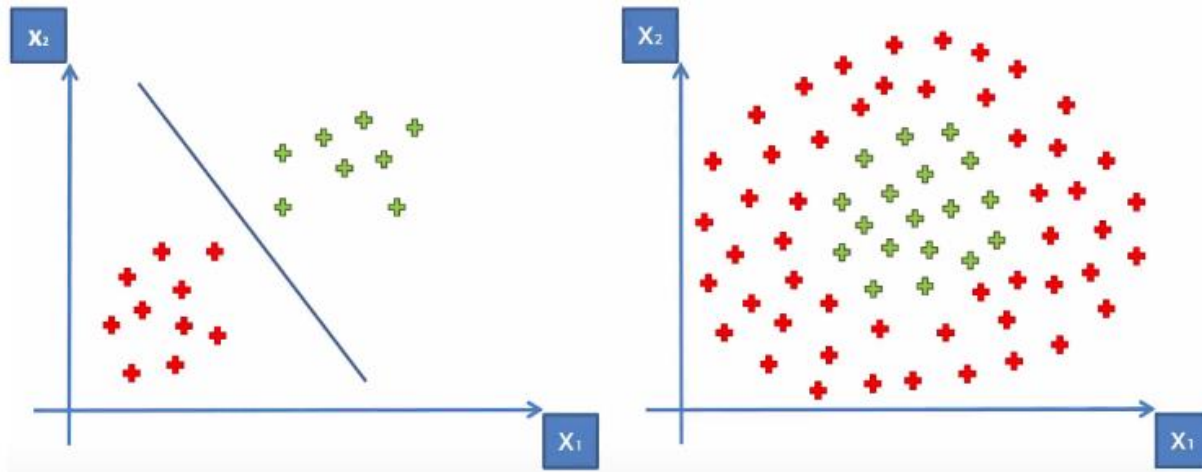
- Deep Learning is **Representation/Feature Learning**





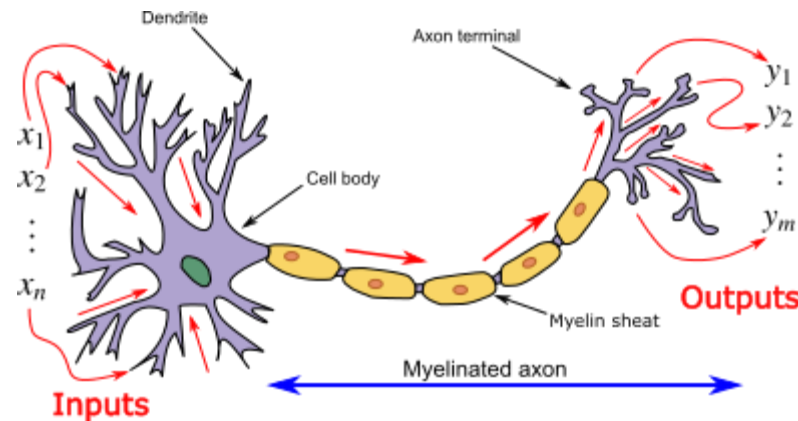
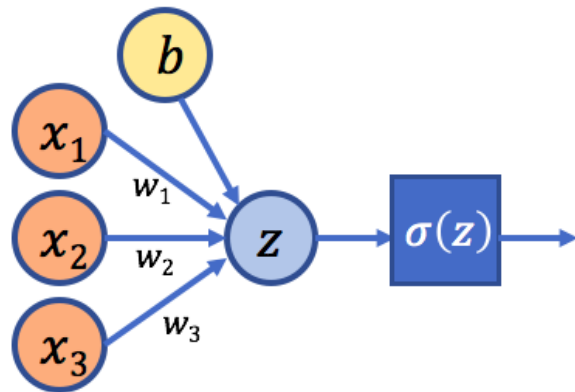
# Deep Learning Intuition

- We would like to learn a **model** or **function** that will give us a desired output given a specific input
- Usually these functions will be **too complex** and highly dimensional for humans to design by hand



# Deep Learning and the Human Brain

- **Not** similar
- Artificial Neural Networks are **vaguely inspired** by biological neural networks
- A lot of effort being put in to understand how exactly our brain works

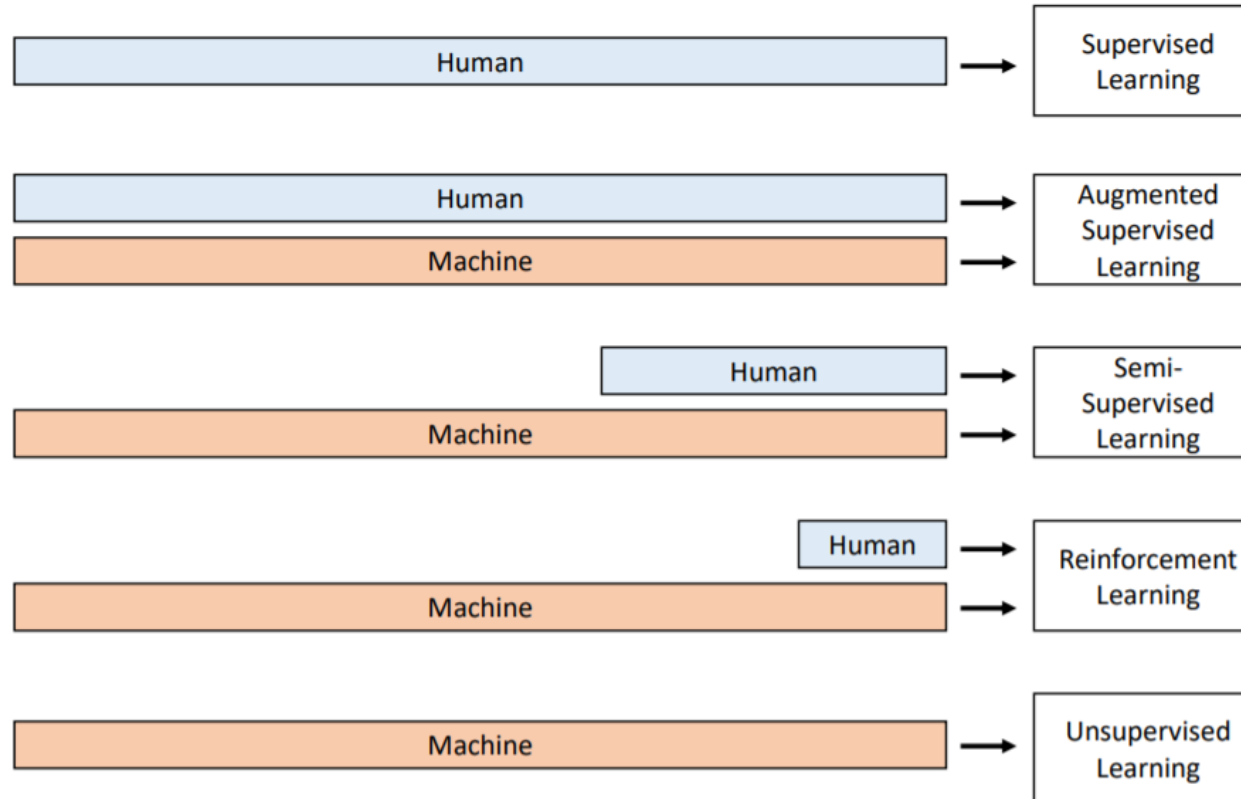




# Types of Learning

- **Supervised Learning**
  - Learn from labelled data (input and target)
  - e.g. map English sentences to corresponding sentences in Mandarin
- **Unsupervised Learning**
  - Learn from unlabelled data
  - e.g. learning important features in data without labels
- **Self-supervised Learning**
  - Learn from data labelled by extracting information from the input data
  - e.g. predict future frames in videos
- **Reinforcement Learning**
  - Learn the optimal decision given the current environment
  - e.g. playing chess, driving a car

# Types of Learning



# Reinforcement Learning

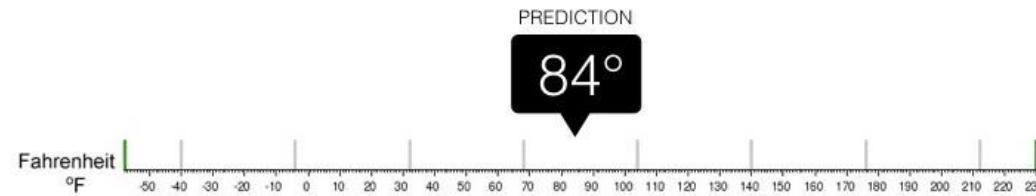


# Learning Tasks: Regression vs Classification



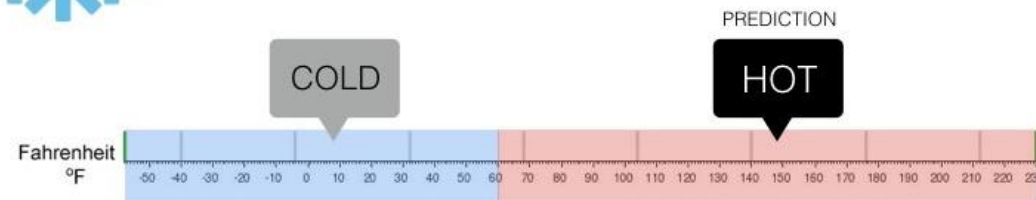
## Regression

What is the temperature going to be tomorrow?



## Classification

Will it be Cold or Hot tomorrow?



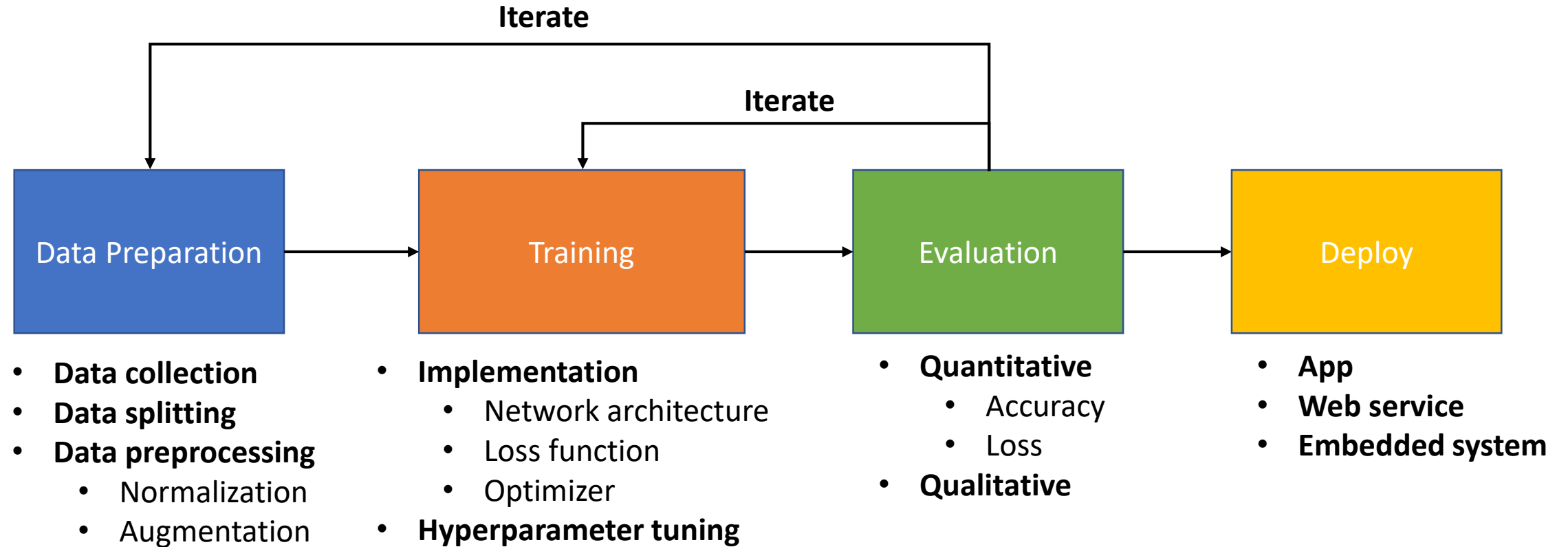
# Deep Learning Frameworks

- **TensorFlow**
  - Developed by Google
  - Dominant in industry<sup>1</sup>
- **PyTorch**
  - Developed by Facebook
  - Dominant in research<sup>1</sup>
- **Both**
  - Primarily used with Python
  - Active development
  - Free and open source
  - Flexible libraries
  - Transferable skills



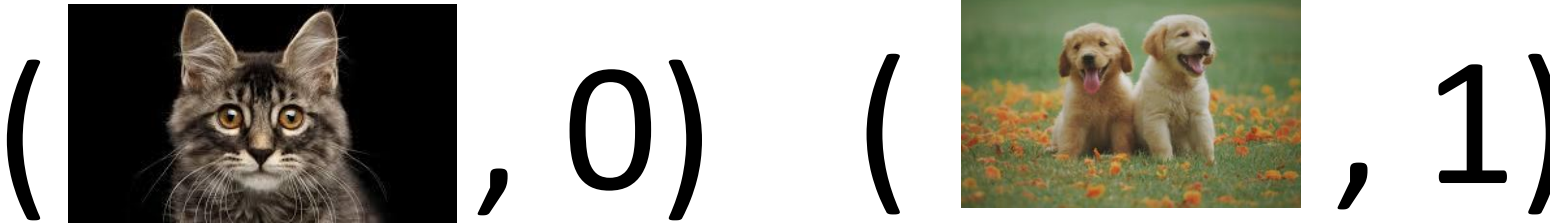
1: <https://thegradient.pub/state-of-ml-frameworks-2019-pytorch-dominates-research-tensorflow-dominates-industry/>

# Deep Learning Steps: Supervised Learning



# Data collection

- **Collect input data and labels**
  - e.g. collect cat and dog pictures online and label cats as 0 and dogs as 1

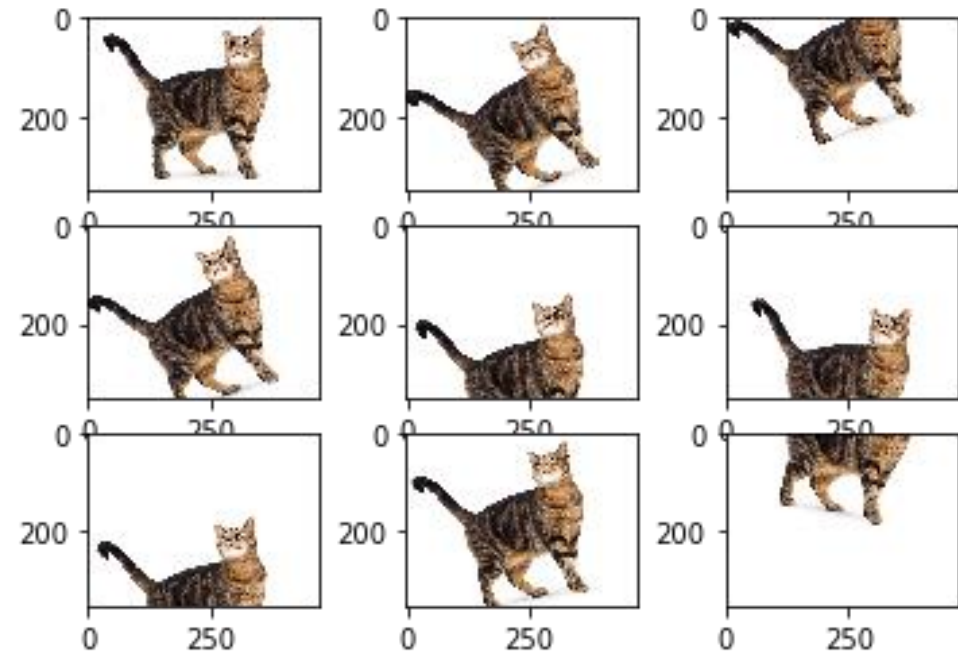


- **There are many publicly available datasets online**
  - Collected and released by research groups
  - e.g Image Classification (ImageNet), Automatic Speech Recognition (LibriSpeech), Object Segmentation (MS-COCO)
- **Good resources**
  - Kaggle
  - GitHub
  - Google Dataset Search



# Data preprocessing

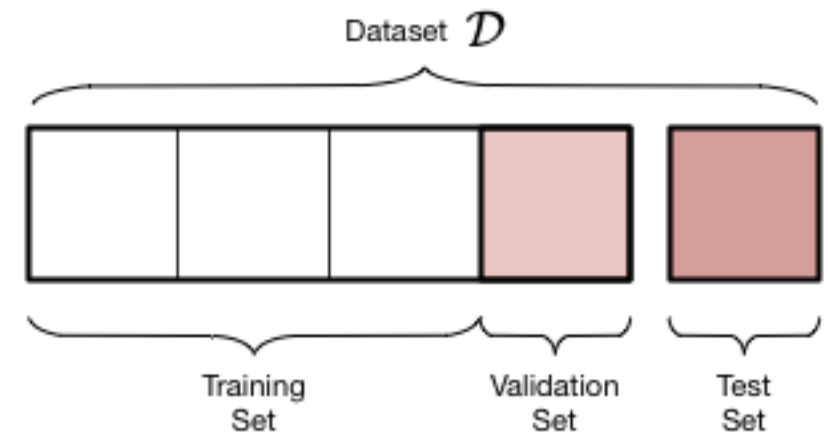
- **Data Cleaning**
  - Remove duplicates
  - Remove bad labels
  - Remove redundant data
- **Data Transformation**
  - Scaling
  - Normalization
  - Augmentation
  - Dimension reduction



Example of image augmentation

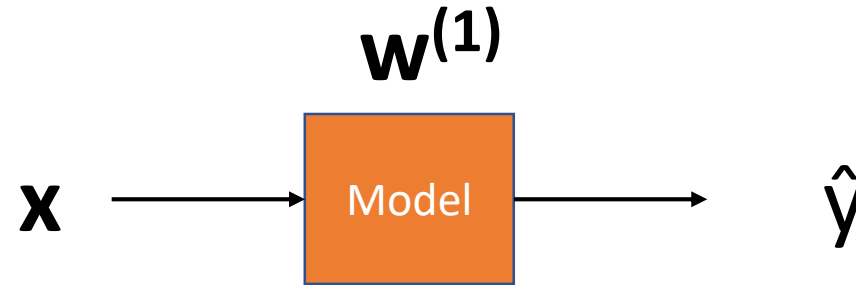
# Data splitting

- Split into **training/testing/validation** sets
  - **Training** set: Training the model
  - **Validation** set: Evaluate the model while tuning the model
  - **Testing** set: Unbiased final evaluation of the model
- Generally you want to have the training set much larger than the **testing** and **validation** set
- **Training** set can come from a different distribution from the **validation/testing** set
  - e.g. cat pictures from the internet vs cat pictures taken by your phone
- The **validation** and **testing** set should come from the same distribution
- Prevent overfitting!



# How do we train the model?

1. Forward pass to obtain prediction



2. Calculate error using cost function,  $J$

$$e = J(\mathbf{w})$$

3. Use backpropagation to calculate gradient

$$\frac{\partial e}{\partial \mathbf{w}^{(1)}}$$

4. Update weights using an optimization algorithm (typically a variant of gradient descent)

$$\mathbf{w}^{(2)} = \mathbf{w}^{(1)} - \alpha \frac{\partial e}{\partial \mathbf{w}^{(1)}}$$

# Binary Classification



: 0

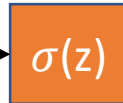
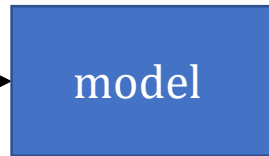


: 1



$x$

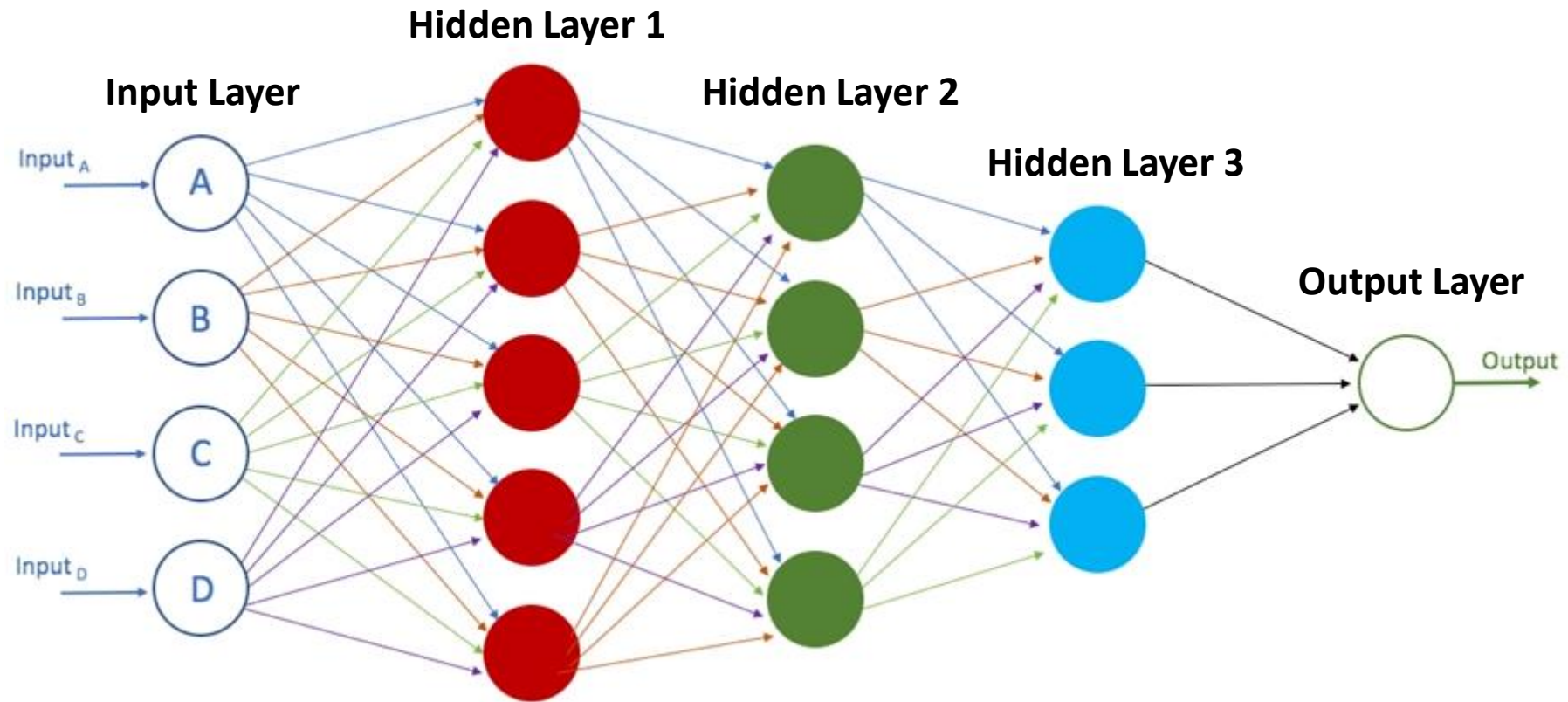
**Forward propagation**



$$P(y = 1|x) = 0.85 \xrightarrow{0.85 > 0.5} \hat{y} = 1$$

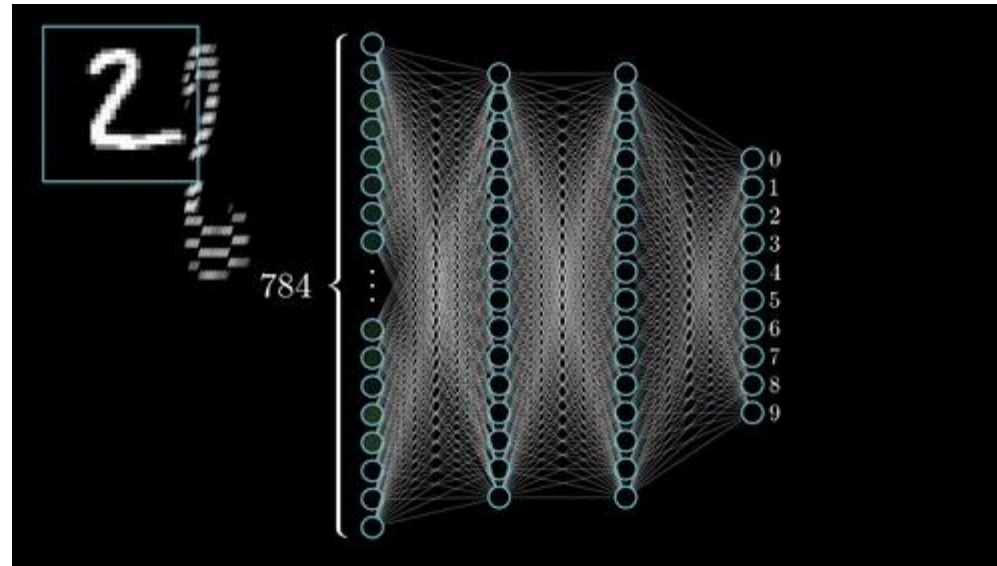
**Loss function:** Binary cross-entropy loss

# Neural Network



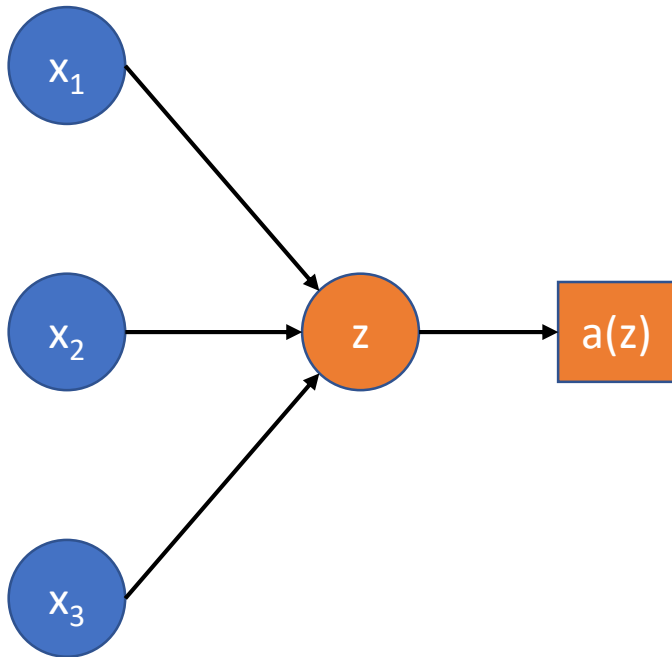
Deep Neural Network from <https://developer.oracle.com/databases/neural-network-machine-learning.html>

# Neural Network

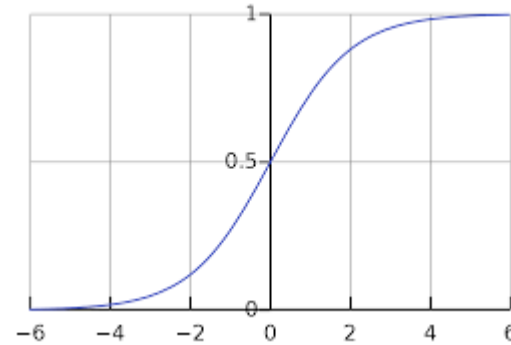


Neural Network GIF from [https://www.youtube.com/channel/UCYO\\_jab\\_esuFRV4b17AJtAw](https://www.youtube.com/channel/UCYO_jab_esuFRV4b17AJtAw)

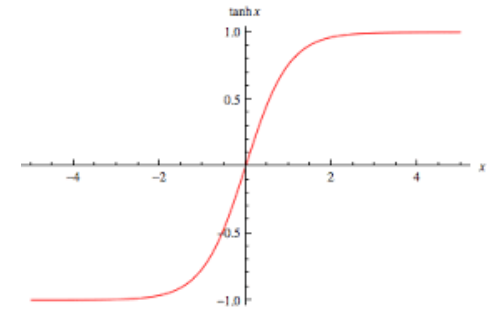
# Activation Functions



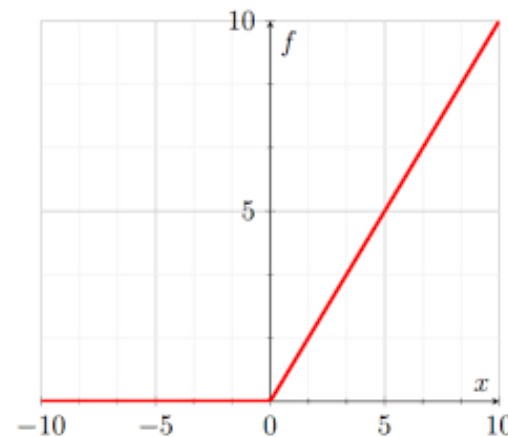
$$\text{Sigmoid}(z) = \frac{1}{1+e^{-z}}$$



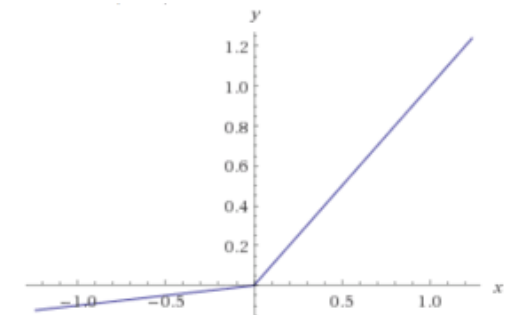
$$\text{Tanh}(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}}$$



$$\text{ReLU}(z) = \max(0, z)$$

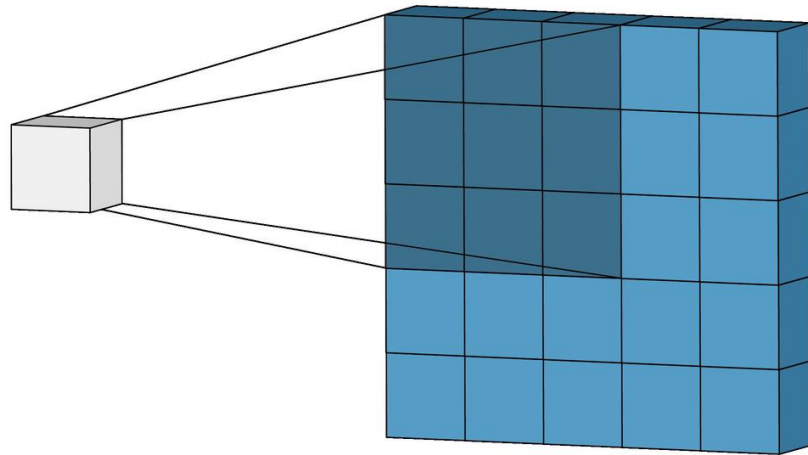


$$\text{Leaky\_ReLU}(z) = \max(0.1z, z)$$



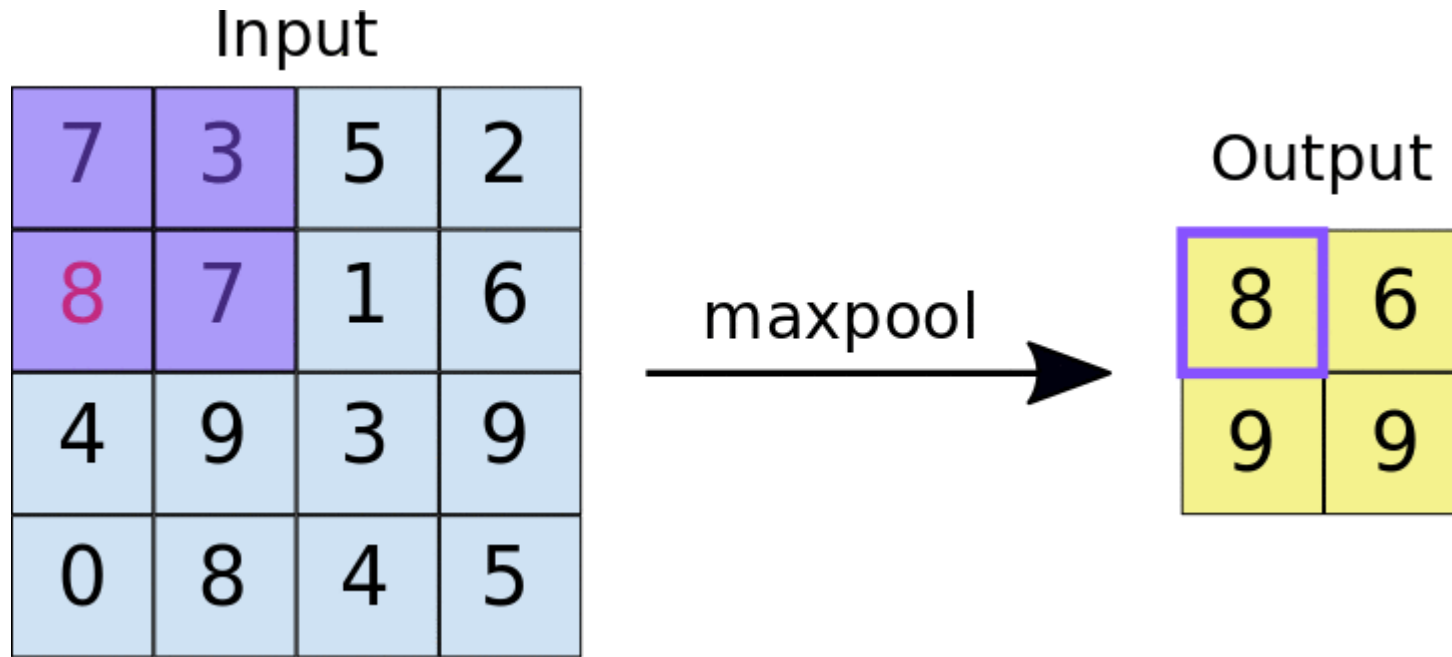


# Convolutional Neural Network



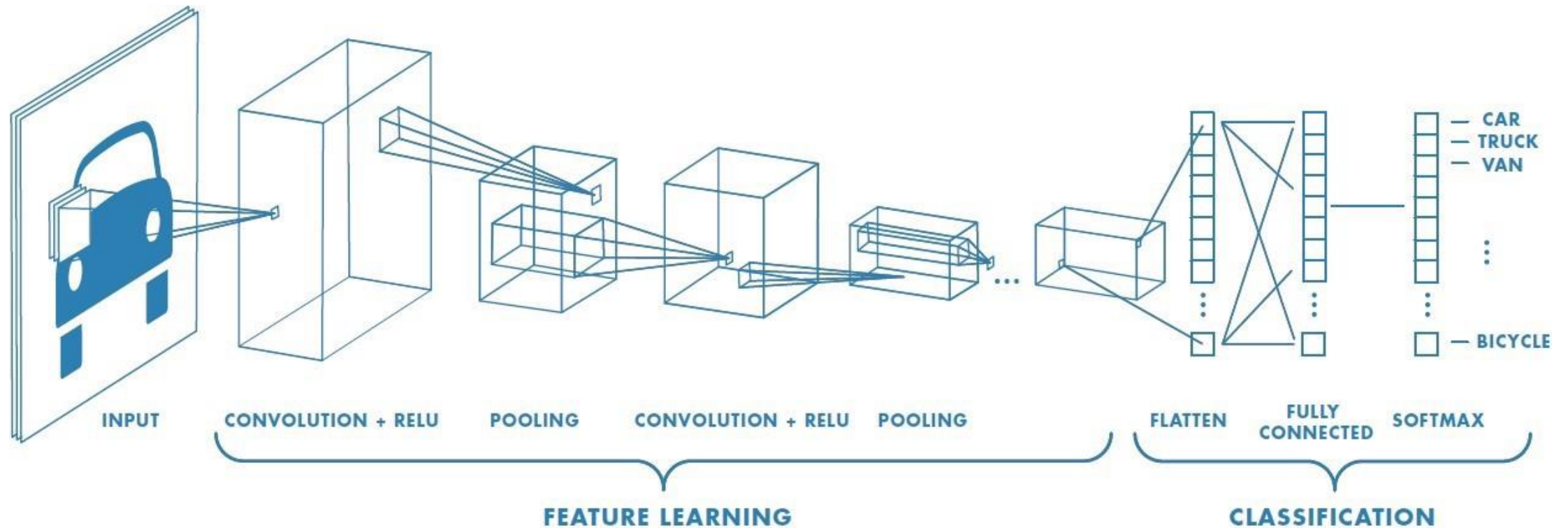
Convolutional Layer GIF from <https://blog.usejournal.com/convolutional-neural-networks-why-what-and-how-f8f6dbebb2f9?gi=3faa9b8cfe4c>

# Max Pool



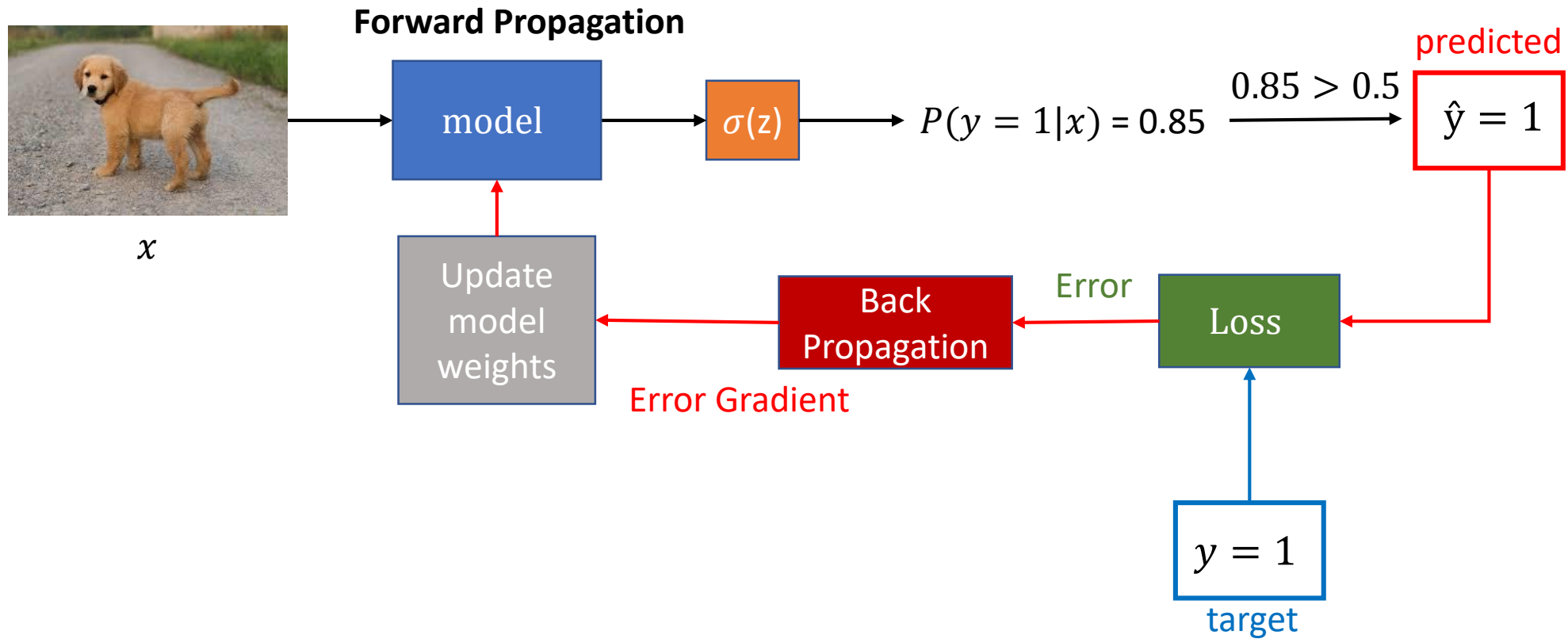
Max Pool layer from <https://developers.google.com/machine-learning/practica/image-classification/convolutional-neural-networks>

# Convolutional Neural Network: Putting it all together



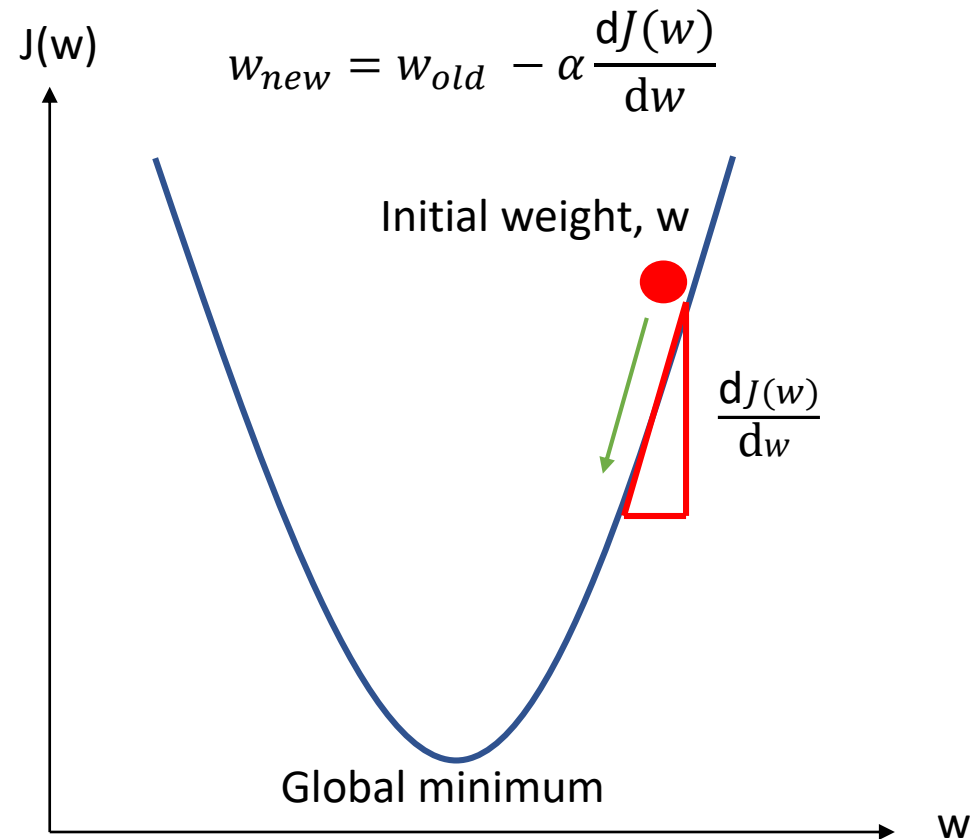
Convolutional Network from <https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53>

# Optimization: Loss Calculation and Back Propagation



# Optimization: Gradient Descent

- Method to optimize our model and find our optimal weights
- We want to find the weights,  $w$  that minimize our cost function,  $J(w)$
- Currently, there are many variants to improve standard gradient descent



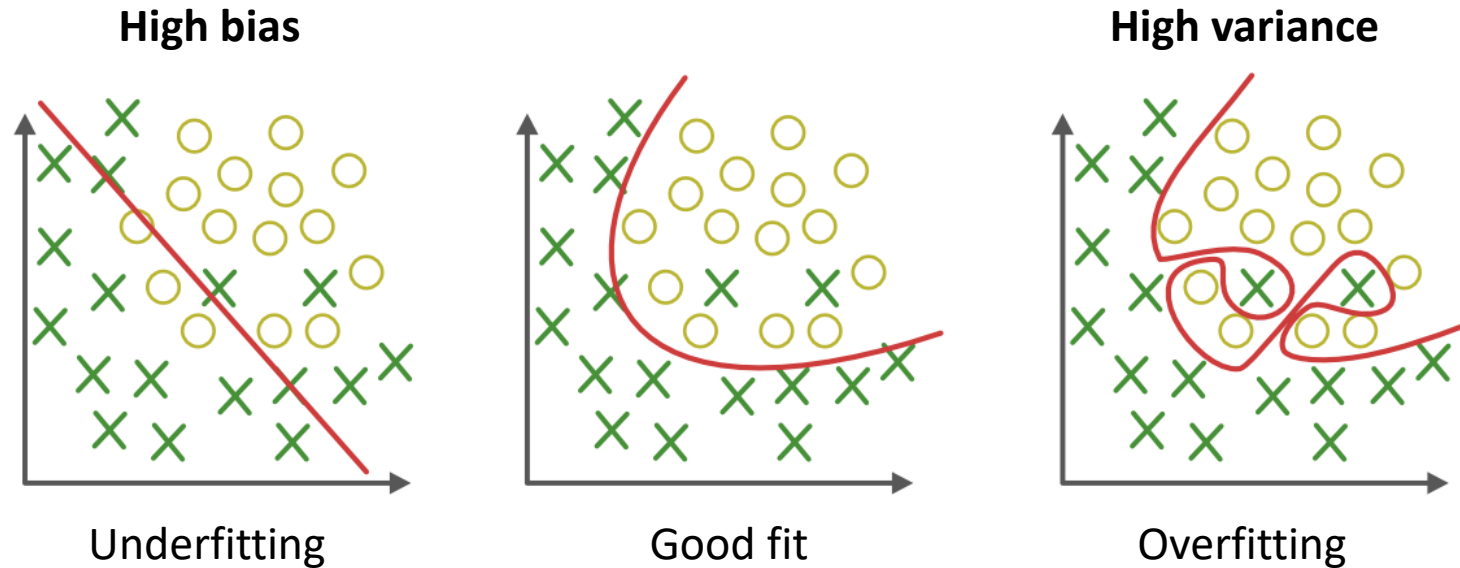
# Evaluating your Model

- **Identify how well the model performs**
- **Identify how well the model generalizes to unseen data samples**
- **Quantitative analysis**
  - Use performance metrics
- **Qualitative analysis**
  - Useful for visual based output



# Underfitting and Overfitting

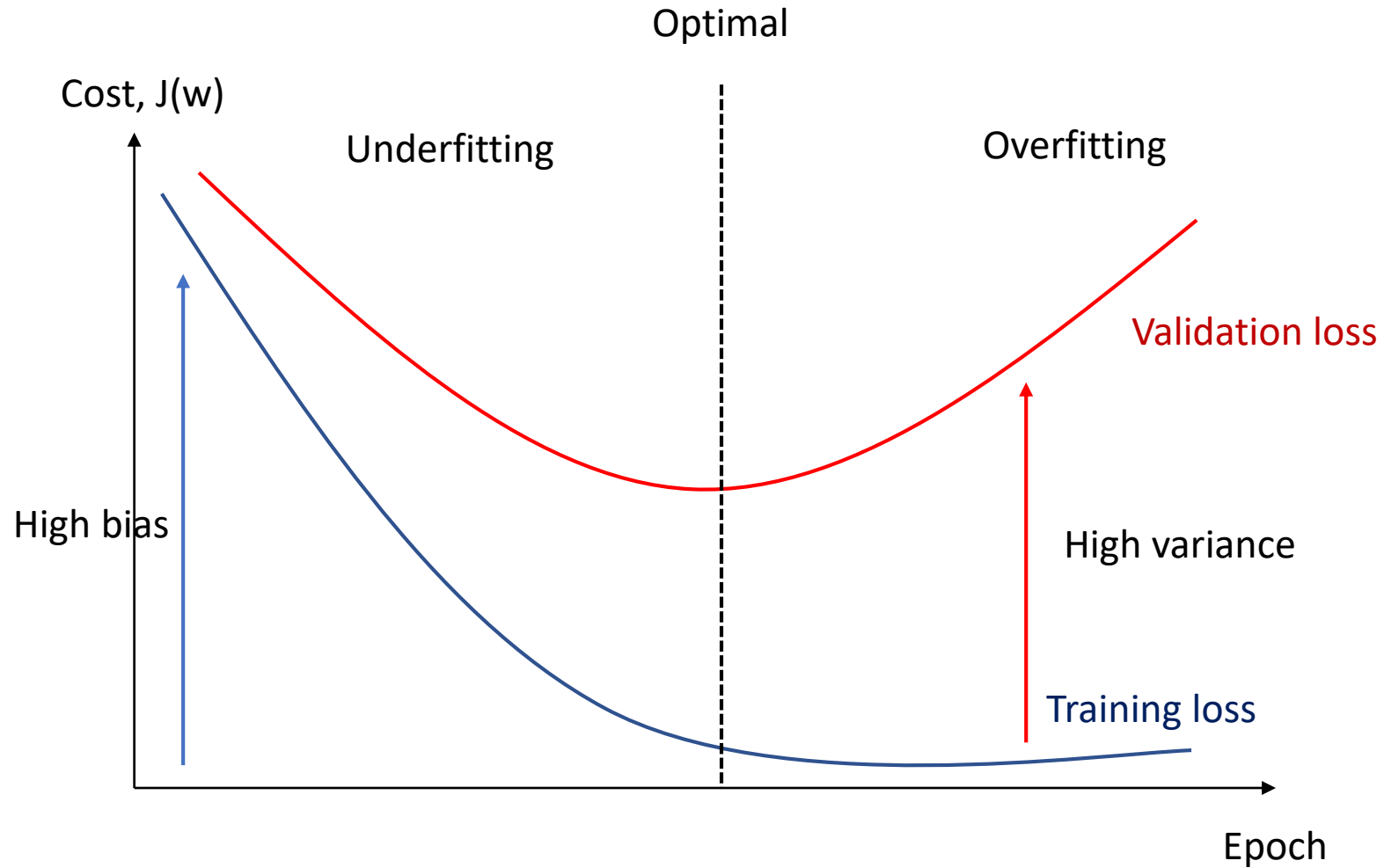
Understanding the model's ability to **generalize** to unseen data



Graphs from <https://towardsdatascience.com/underfitting-and-overfitting-in-machine-learning-and-how-to-deal-with-it-6fe4a8a49dbf>



# Underfitting and Overfitting



How do we deal with overfitting? - **Regularization**

# Next Steps

- **Fix Problems**
  - Is the model performing as expected?
- **Dataset**
  - Fix mislabeled data
  - Add more data to cover the worst performing samples
    - e.g. add more cloudy images
- **Hyperparameter tuning**
  - Find the best performing model
- **Regularization**
  - Prevent overfitting
- **Improving the model**
  - Updating the loss function
  - Updating the model architecture

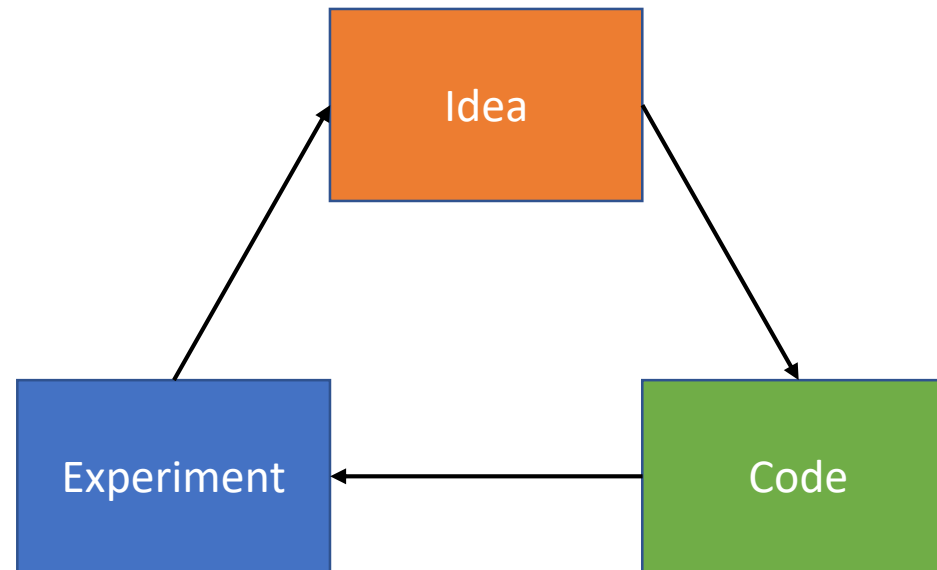


Cat?



# Machine Learning Research is Iterative

- **Finding good models is empirical**
- **Research cycle:**
  1. Develop algorithm
  2. Implement algorithm and train model
  3. Evaluate model and identify weakness
  4. Repeat until satisfied



# Improving Neural Networks

- **Model size**
- **Model training time**
- **Model performance**
  - Accuracy
  - Inference speed

Space

Time

Performance

# Model Tuning

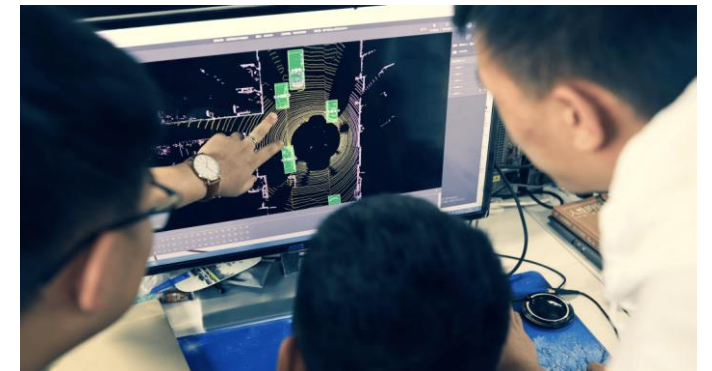
Tweak the network until we find the configuration that gives us the best performance

- **Size of network**
  - Number of hidden units
  - Number of layers
- **Activation function**
- **Cost function**
- **Optimizer**
- **Weight initialization**
- **Types of layers**
- **Batch size**
- **Learning rate schedule**
- .... a lot more!



# Barrier to Entry

- **Computational resources**
  - Deep learning research is computationally intensive
  - Finding a good model requires a lot of iteration
  - Good GPUs can cost a lot
- **Datasets**
  - Deep learning models are data hungry
  - Generally, the more data you have, the better your model will be
  - Some types of data are not easy to collect<sup>1</sup>
- **Expertise**
  - A lot of resources online makes it easy to learn
  - In-depth understanding takes some time
  - Competing with large companies for graduates



1: <https://time.com/5518339/china-ai-farm-artificial-intelligence-cybersecurity/>

# Where are we now?

- Most big questions of intelligence have not been answered nor properly formulated<sup>1</sup>
- Research is happening all over the world
- Deep Learning Frameworks are constantly being improved
- More industries are adopting deep learning into their systems
- We have come a long way and we still have much left to do!



# Useful Resources

- **Coursera Deep Learning Specialization by deeplearning.ai**
  - Introductory course to Deep Learning
  - Good for beginners
- **Coursera TensorFlow in Practice Specialization by deeplearning.ai**
  - Tutorials on using TensorFlow
- **PyTorch Tutorials at pytorch.org**
  - Tutorials on using PyTorch
- **Deep Learning Book by Ian Goodfellow, Yoshua Bengio and Aaron Courville**
  - Introductory textbook on Deep Learning
- **GitHub**
  - Code examples
  - Datasets
- **Quora or Stack Overflow**
  - Asking questions
- **Lex Fridman Youtube Channel**
  - Podcasts
  - Lectures

Deep Learning is really big now so there's a lot of resources out there if you search for it!

Questions?