First Step to Practical Machine Learning

Knowledge Sharing for CPE/SKE students

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October 30, 2018

Before we start...

Make sure these are installed on your computer.

This page is a guide for installing on Windows

- Python 3.6: Download and install at `https://www.python.org`
- NumPy, Scipy, Matplotlib, Scikit-learn, MLxtend:
  Run `pip install numpy scipy matplotlib sklearn mlxtend`

Outline

Introduction to Machine Learning

What is Machine Learning?

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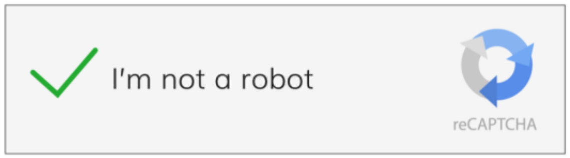

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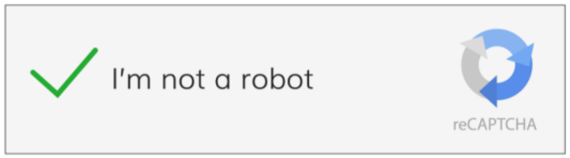

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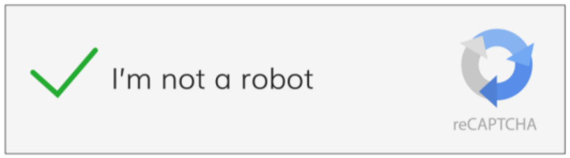

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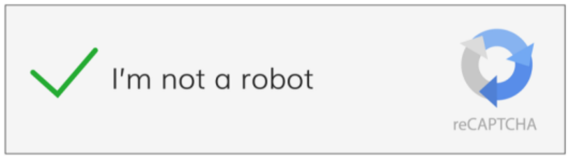

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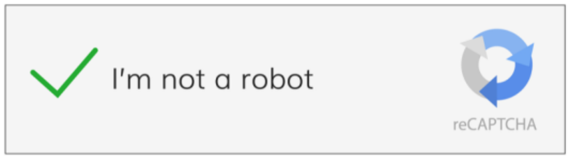

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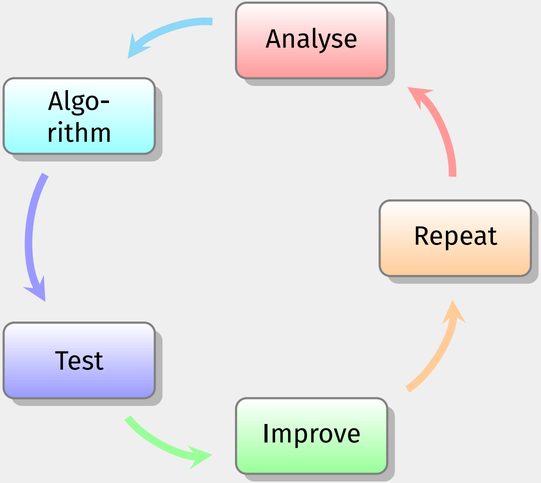
  - Recaptcha helps stop millions of spam a day.
  - In some old days, we have to type Captcha texts to distinguish ourself from bots.
  - How is it possible that with a single click, an automated system can distinguish bots from humans?

Traditional programming approach



Analyse

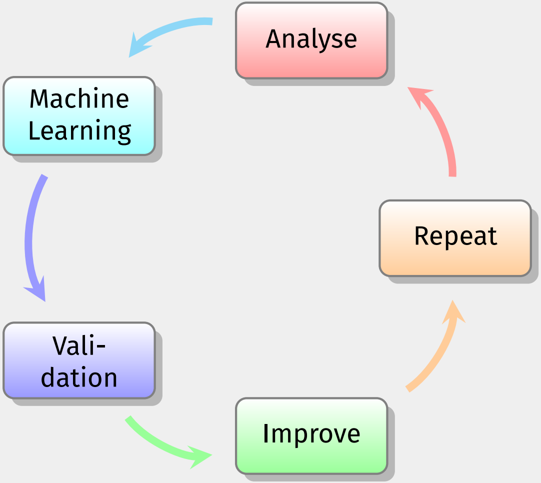
Algo-rithm

Test

Improve

Repeat

Machine learning approach



Analyse

Machine Learning

Vali- dation

Improve

Repeat

In other words...

Machine Learning

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Machine Learning

= Data + Data analysis algorithm

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Machine Learning

= Data + Data analysis algorithm

= Adapt to change

Machine Learning Problems

Types of Machine Learning problems

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1. Supervised learning

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2. Unsupervised learning

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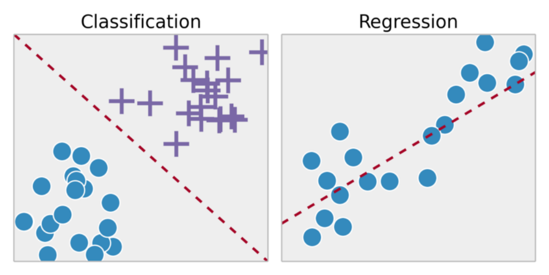
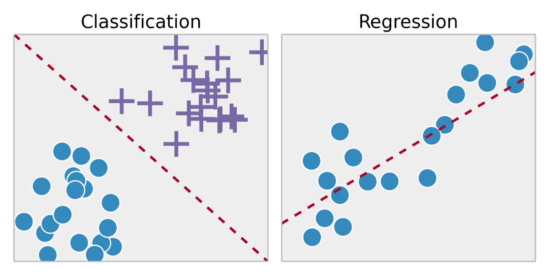
1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

Supervised learning



Supervised learning



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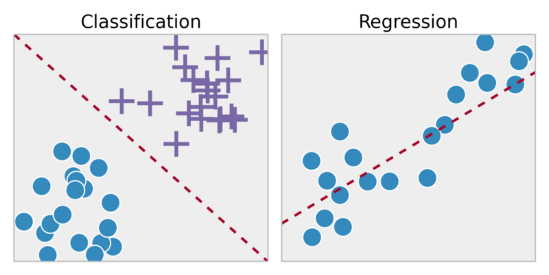

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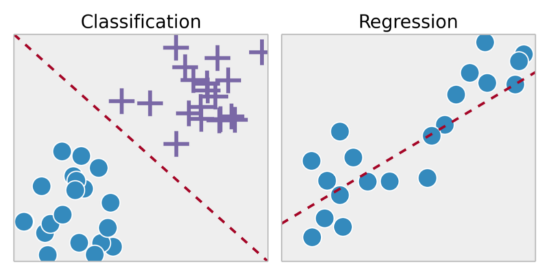
Supervised learning



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  - Classification: On the discrete data

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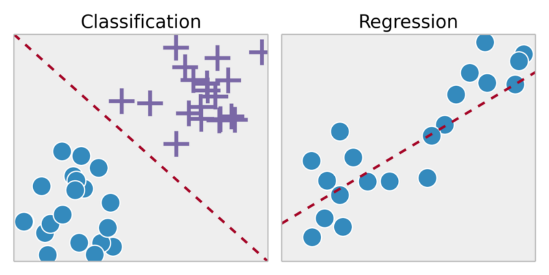

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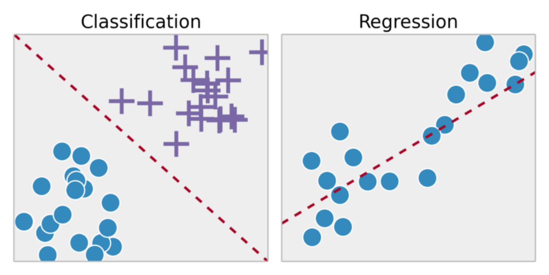

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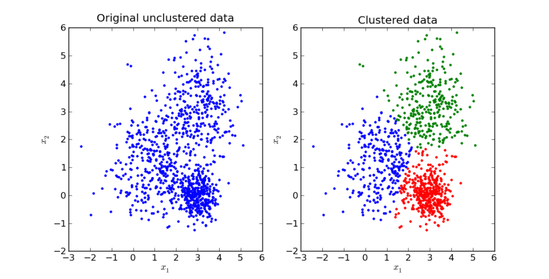
- Two main supervised learning problems
    - Classification: On the discrete data
    - Regression: On the continuous data
- Example problems: Spam E-mail detection, Facial recognition

Unsupervised learning



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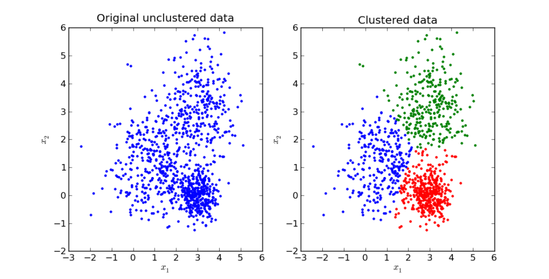

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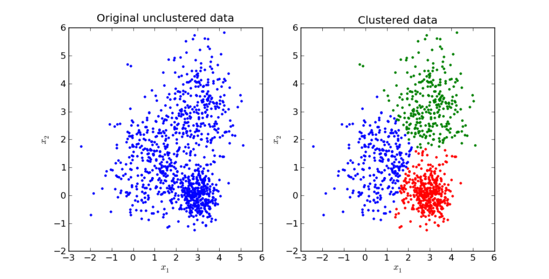
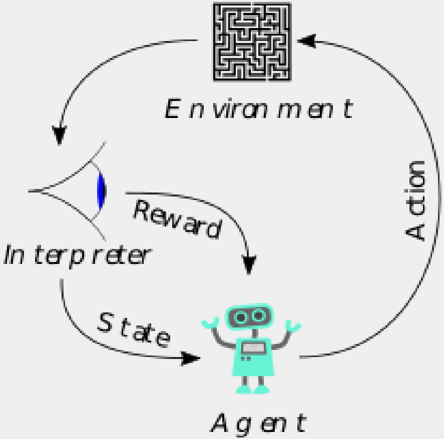


- Discover **hidden** structure in **non-labelled** data.
- Example: Clustering, Generative models

Reinforcement learning



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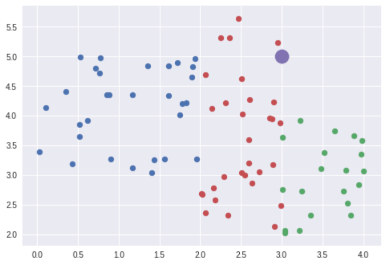

Data

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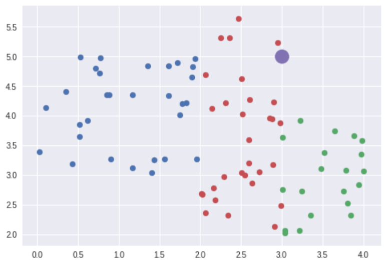

Determine which group should the purple dot be in (red/green/blue) by **checking the colour of its nearest dot.**

Data

Method

Beginning with our first model

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k-NN algorithm

To classify label of a data point, get *k* nearest data points to the data point, and select the major label among those data points.

Coding time!

Machine Learning Process

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- Train

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- Train
- Test

Machine Learning Process

- Train
- Test

(There’ll be more of this, trust me.)

Choosing the parameter for k-NN algorithm

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Choosing the parameter for *k*-NN algorithm

What is the bad way to choose *k*?

- What if we choose *k* = # of all points?
  - What will happen if our dataset's got 3 labels of A, B, C with 10, 20, and 30 data points of each?

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- What if we choose $k = 1$?
  - Let's try!

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  - In other words, **don’t test and train model on the same set of data.**

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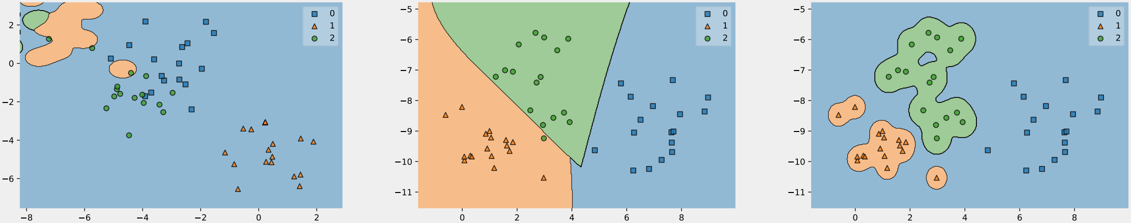
Warning! This is a simplified Machine Learning model training process, there are more to concerns!

Overfitting and underfitting

Which decision region is good?



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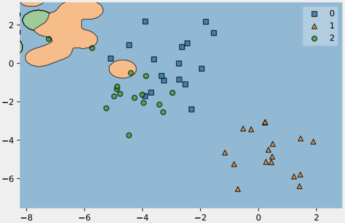

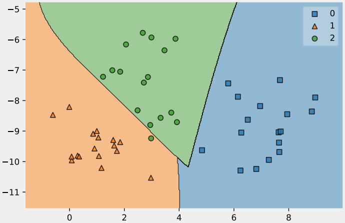

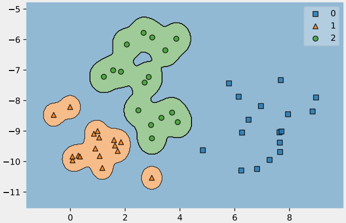

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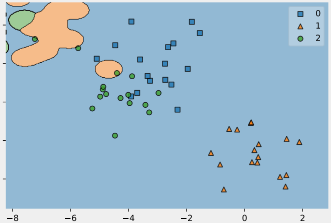

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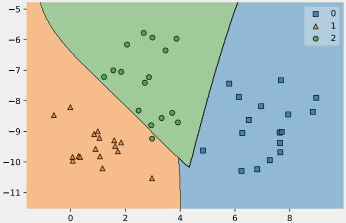

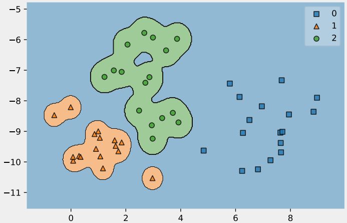

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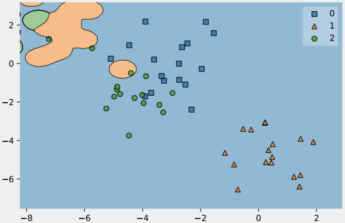

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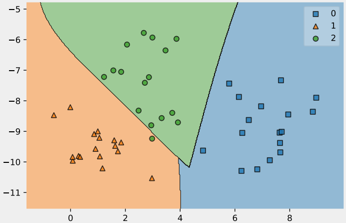
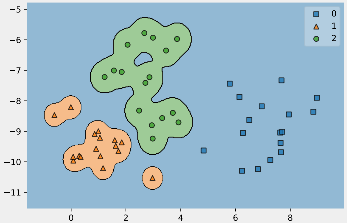


Good fit: The model recognises data pattern **generally**



Overfit: The model **remembers** data pattern instead of generalising.

Overfitting and underfitting

Good model must **generalise**

Parameter Optimisation

- Actually, the key point in *k*-NN algorithm is choosing *k* points with the least **distant**.
- What is **distant**?

Norm for k-NN algorithm

Norm

In linear algebra, a **norm** is a function that assigns a strictly positive length or size to each vector in a vector space - except for the zero vector, which is assigned a length of zero.

Given $\vec{x}$ as an N-dimension vector of $\begin{bmatrix} x_1 & x_2 & \dots & x_n \end{bmatrix}$

- l_1 Norm: $|x|_1 = \sum_{i=0}^{N} |x_i|$ (Manhattan)
- l_2 Norm: $|x|_2 = \sqrt{\sum_{i=0}^{N} x_i^2}$ (Euclidian)
- l_p Norm: $|x|_p = \left(\sum_{i=1}^{n} |x_i|^p\right)^{1/p}$ (Minkowski)

Algorithms for Machine Learning Classification Problem

Algorithms for Machine Learning Classification Problem

k-NN is a very simple intuition for machine learning algorithms. However, there exists more algorithm that performs well to other problems.
Example algorithms:

- Naïve Bayes
- SVM
- Decision Tree
- Logistic Regression

Naïve Bayes

	Gender	Hair
1	M	Long
2	M	Short
3	F	Long
4	F	Long
5	F	Short

Bayes Theorem

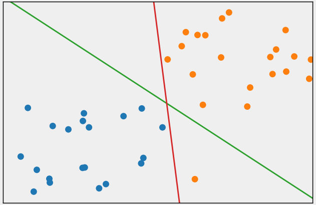
$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(B|A) \times P(A)}{P(B)}$$

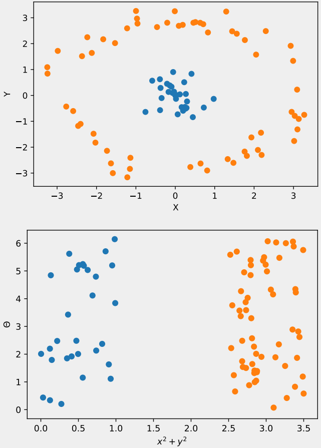
Can we *guess* the gender from hair's length?

- $P(\text{Male}|\text{Long hair}) = \frac{1}{3}$
- $P(\text{Female}|\text{Long hair}) = \frac{2}{3}$

Therefore, we guess that the long-haired person is more likely to be a female.

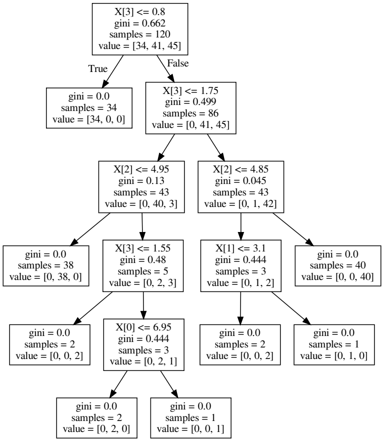
Support Vector Machines (SVM)





- Goal: to draw a line to separate groups of data
- Ideal good line: maximising the distant between the line and classes of data points
- What if the data is not linearly separable? **Kernel tricks**

Decision Tree



- Creating an if-else conditions automatically
- Nested conditions with a parameter to determine how does the separating of the "tree" performs.

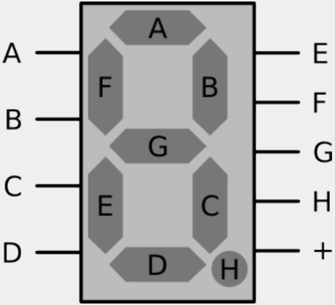
Figure: xkcd - Compiling

THE #1 PROGRAMMER EXCUSE FOR LEGITIMATELY SLACKING OFF:
"MY CODE'S ~~COMPILING.~~" TRAINING.
HEY! GET BACK TO WORK!
TRAINING!
~~COMPILING!~~
OH. CARRY ON.

Figure: xkcd - Compiling

Problems for Machine Learning

7-Segment display



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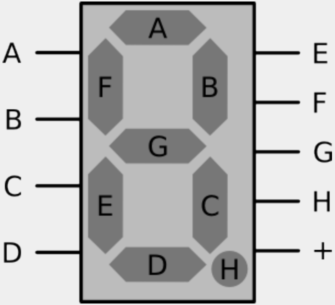

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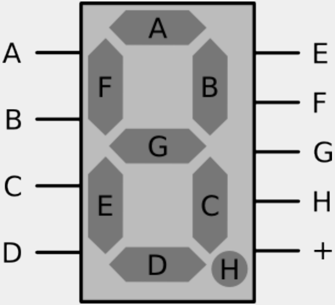

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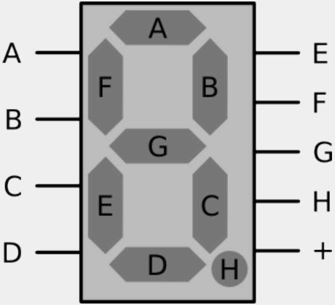

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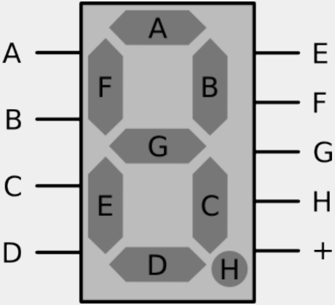

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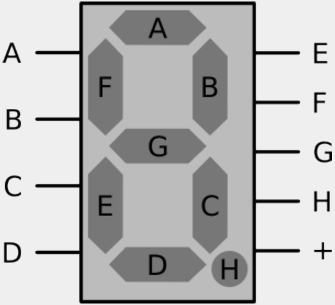


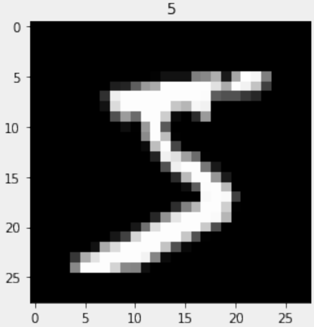
Problem

When the list of the bulb that went on were given, can we determine the number?

Not only yes, but *easily* yes!

```
if led_on == (b, c):
    return 1
elif led_on == (a, b, g, e, d):
    return 2
...
```

Handwriting



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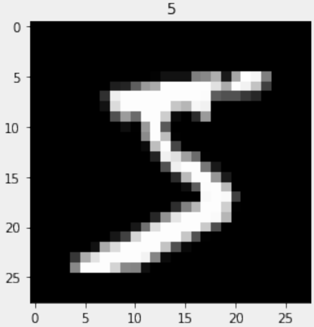

Problem

When the image of the handwriting were given, can we determine the number?

With an **explicit algorithm**? Obviously no! There are too many ways of drawing the number!

MNIST Dataset

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- 28*28 pixel images of handwritten numbers (0-9)

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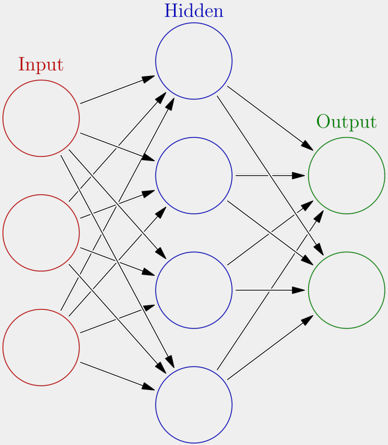
- 10,000 testing images

k-NN with MNIST

- Training: Pretty fast, no calculations on training phase
- Testing: **thinking**
  - 60,000 data points to calculate the distant + 10,000 data points to test
  - = 600,000,000 calculations to be made
    (this excludes sorting, of which is a $\mathcal{O}(n)$ process)
  - = **(relatively) slow**

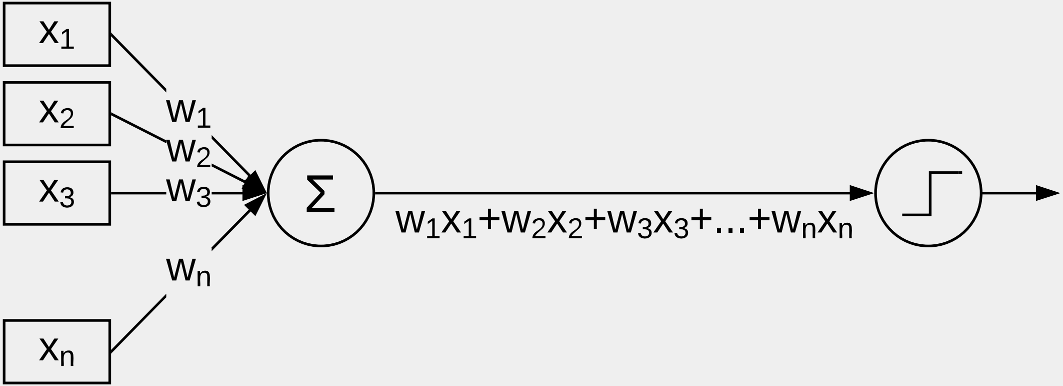
Neural Networks

Artificial Neural Networks (ANN)



This seems complex, right? We’ll get started a little by little...

Perceptron



Linearly Separable Problem

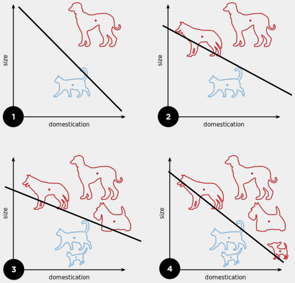


Figure: Linearly Separable Problem (Courtesy: Elizabeth Goodspeed from Wikimedia Commons)

- Now our problem is that the perceptron is a **linear classifier**, that means it could only separate datas that is linearly separable.
- Real-world problems are not that easy to separate
- How can we solve this problem?