

FIRST STEP TO PRACTICAL MACHINE LEARNING

KNOWLEDGE SHARING FOR CPE/SKE STUDENTS

SIRAKORN LAMYAI

STUDENT, KASETSART U.

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ACKNOWLEDGEMENTS

Resources on this slides are mainly adapted and rearranged from

- W. Jitkrittum: Machine Learning Fundamentals I
- K. Muandet: Machine Learning Fundamentals II
- Google's Machine Learning Crash Course

BEFORE WE START...

Make sure these are installed on your computer.

- Python 3.6
- NumPy, Scipy, Matplotlib, Scikit-learn, MLxtend:
Run `pip install numpy scipy matplotlib sklearn mlxtend`
- MNIST loader
`pip install git+https://github.com/datapythonista/mnist.git`

- 1 Introduction to Machine Learning
 - What is Machine Learning?
- 2 Machine Learning Problems
 - Supervised learning
 - Unsupervised learning
 - Reinforcement learning
- 3 Model
 - The Goal of Machine Learning

- 4 Machine Learning Process
 - Evaluating Machine Learning Performance
- 5 Algorithms for Machine Learning Classification Problem
- 6 Problems for Machine Learning
 - Handwriting recognition
- 7 Neural Networks
- 8 Your next step into Machine Learning

INTRODUCTION TO MACHINE LEARNING

WHAT IS MACHINE LEARNING?

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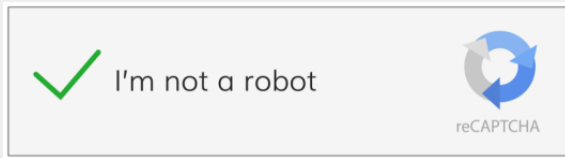


I'm not a robot



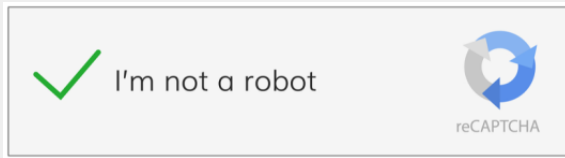
reCAPTCHA

WHAT IS MACHINE LEARNING?



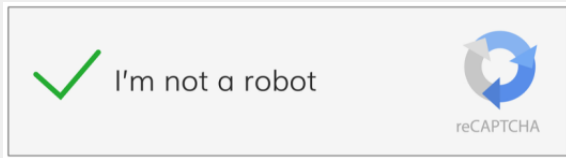
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WHAT IS MACHINE LEARNING?



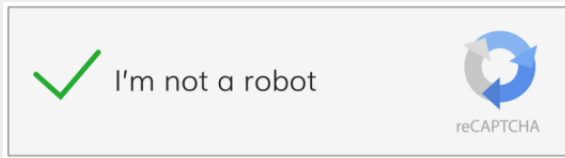
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WHAT IS MACHINE LEARNING?



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WHAT IS MACHINE LEARNING?



■ This is Recaptcha.

- ▶ 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?

Machine Learning

Machine Learning

= Improves performance on a specific task.

MACHINE LEARNING PROBLEMS

TYPES OF MACHINE LEARNING PROBLEMS

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1. Supervised learning

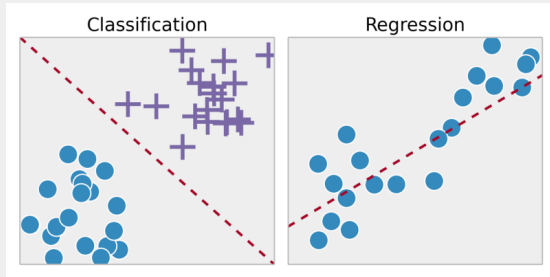
TYPES OF MACHINE LEARNING PROBLEMS

1. Supervised learning
2. Unsupervised learning

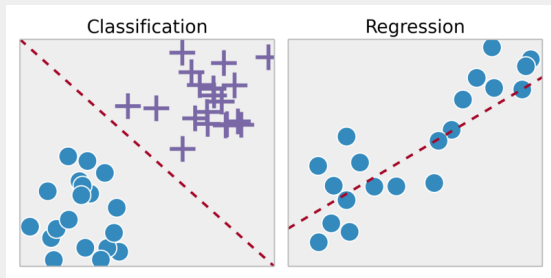
TYPES OF MACHINE LEARNING PROBLEMS

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

SUPERVISED LEARNING

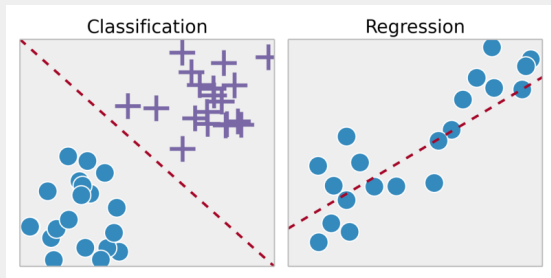


SUPERVISED LEARNING



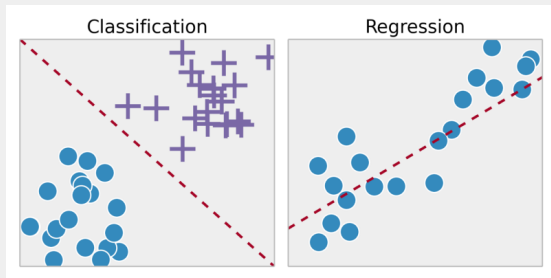
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SUPERVISED LEARNING



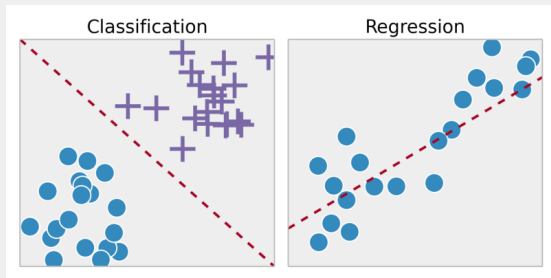
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SUPERVISED LEARNING



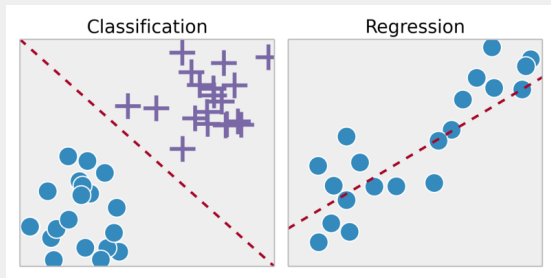
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 - ▶ Classification: On the discrete data

SUPERVISED LEARNING



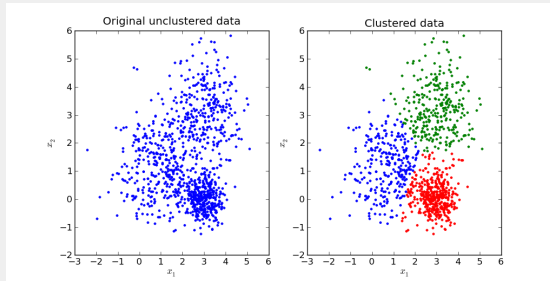
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 - ▶ Regression: On the continuous data

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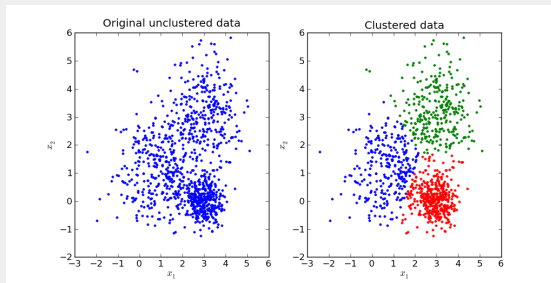


- Given a **training set** for the data, find a **model** to **generalise** well to **unseen** data.
- Two main supervised learning problems
 - ▶ Classification: On the discrete data
 - ▶ Regression: On the continuous data
- Example problems: Spam E-mail detection, Facial recognition

UNSUPERVISED LEARNING

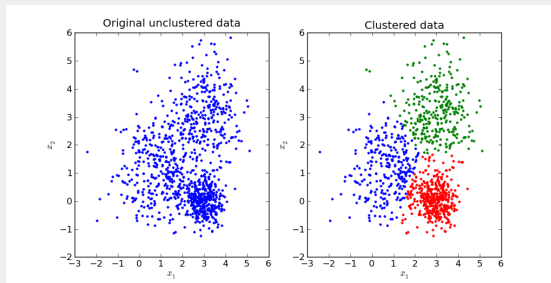


UNSUPERVISED LEARNING



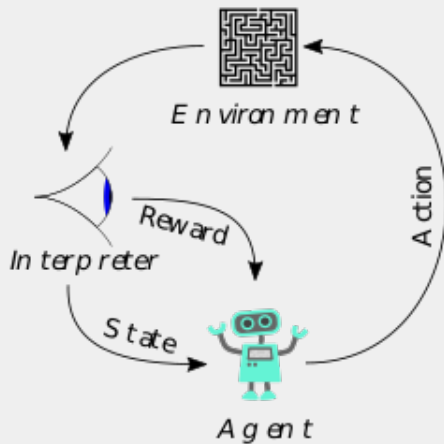
- Discover **hidden** structure in **non-labelled** data.

UNSUPERVISED LEARNING



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

REINFORCEMENT LEARNING



MODEL

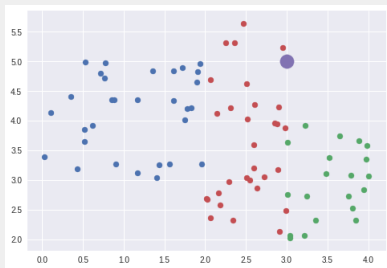
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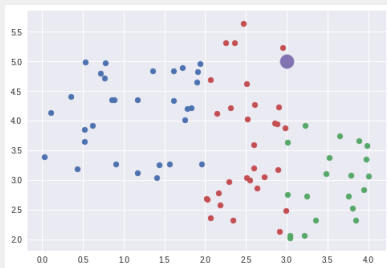
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Data

MODEL

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Data

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

Method

Generalise

- We want our model to know how the **data pattern** looks like
- Our model should not "adhere" to one set of data, but instead knows the pattern of all the data.
- Therefore, we want our model to **generalise** over any set of data, given the small portion of data that we used to teach the model.

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.

MACHINE LEARNING PROCESS

CHOOSING THE PARAMETER FOR k -NN ALGORITHM

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What is the bad way to choose k ?

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CHOOSING THE PARAMETER FOR k -NN ALGORITHM

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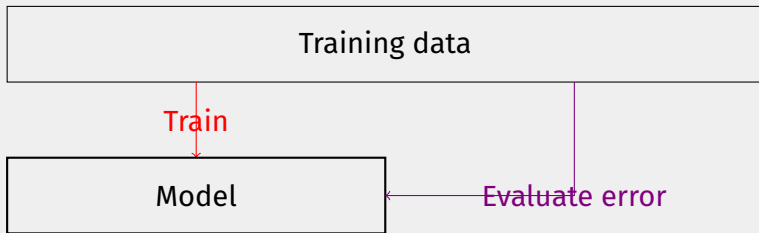
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 - ▶ Answer: Our model will always answer the labels with the highest data point count.
- What if we choose $k = 1$?
 - ▶ Let's try!

TRAINING ERROR



Loss function

$$L(y, \hat{y}) = \begin{cases} 0 & y = \hat{y} \\ 1 & y \neq \hat{y} \end{cases}$$

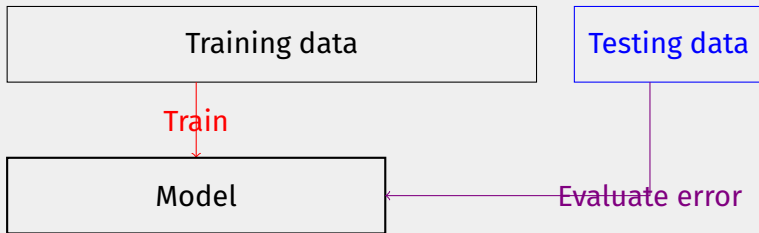
Error

$$\sigma = \frac{1}{N} \sum_{i=0}^N L(y_i, \hat{y}_i)$$

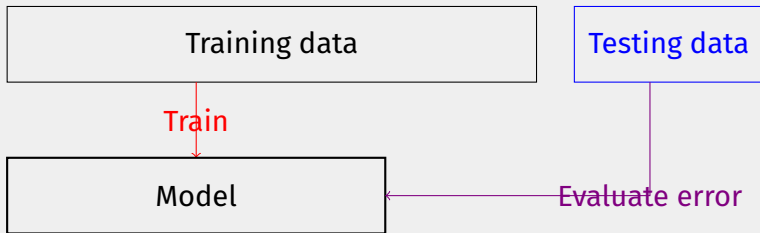
WHAT WENT WRONG WITH OUR INTUITION?

- Evaluating error with a data points that our model had already seen is bad.
- Why? Because our model already knows the answer to that data point! It could just simply answer by looking at the "answer key"
- So how should we evaluate our model?

TRAINING AND TESTING SET

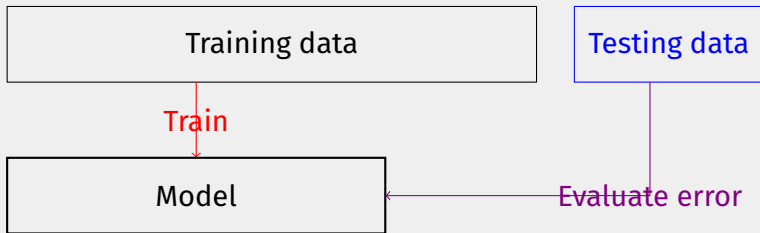


TRAINING AND TESTING SET



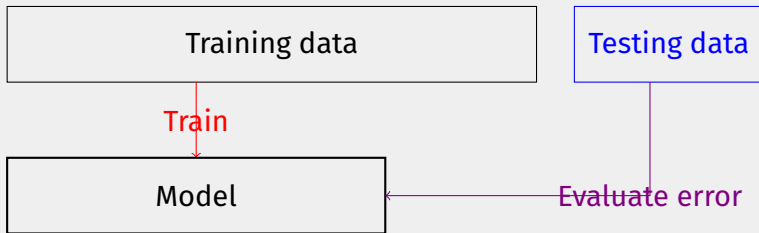
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TRAINING AND TESTING SET



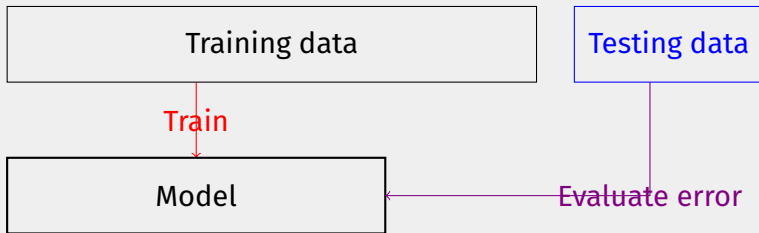
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TRAINING AND TESTING SET



- We separate our dataset into 2 parts: the **training set** and **testing set**
 - ▶ Our model sees the correct label of the training set, but not the testing set.
 - ▶ We all know the correct label of both the training and testing set.
 - ▶ Teach our model with the training set, see how it performs with the testing set.

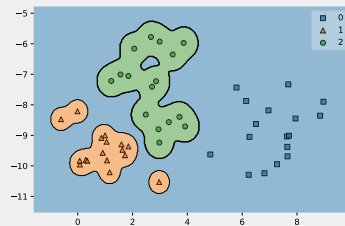
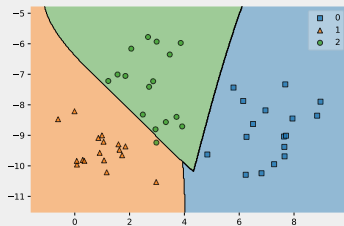
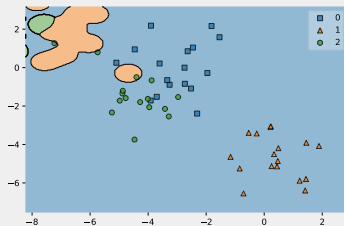
CHOOSING THE BEST k

What will happen if...

- our k is too small?
- our k is too large?

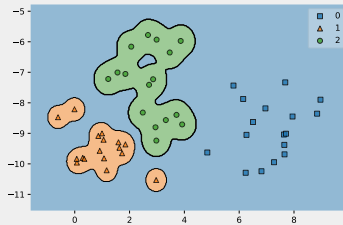
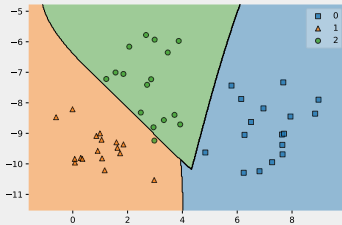
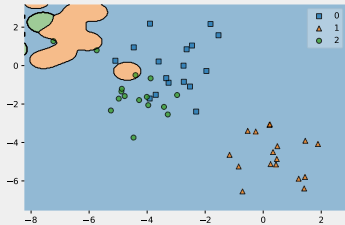
OVERFITTING AND UNDERFITTING

Which decision region is good?



OVERFITTING AND UNDERFITTING

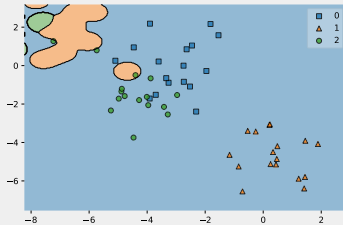
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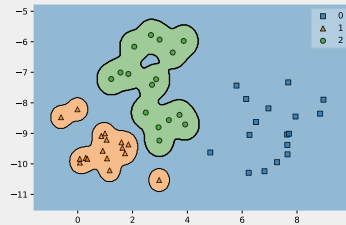
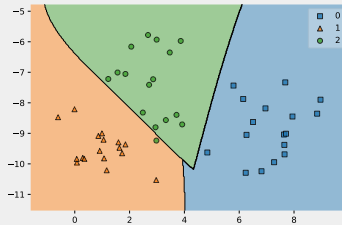
Underfit: The model fails to recognise data pattern

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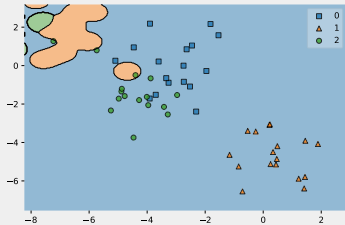
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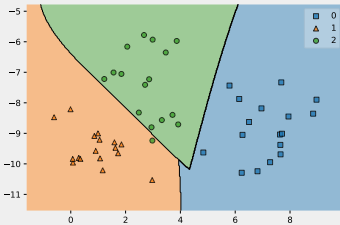
Overfit: The model **remembers** data pattern instead of generalising.

OVERFITTING AND UNDERFITTING

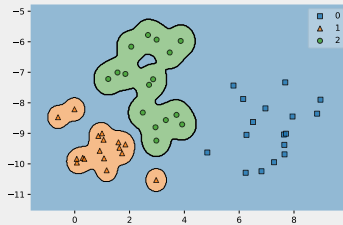
Which decision region is good?



Underfit: The model fails to recognise data pattern



Good fit: The model recognises data pattern generally



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

Good model must **generalise**

- 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 $[x_1 \ x_2 \ \dots \ x_n]$

- 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: $|x|_p = (\sum_{i=1}^n |x_i|^p)^{1/p}$ (Minkowski)

ALGORITHMS FOR MACHINE LEARNING CLASSIFI- CATION 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

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

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

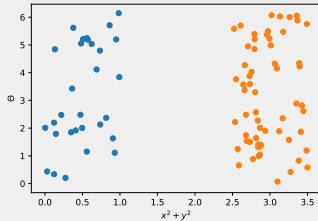
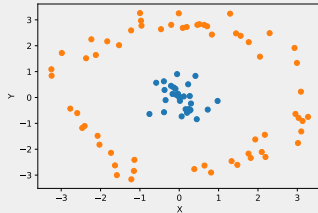
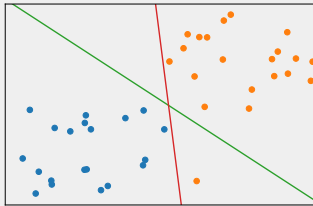
■ $P(\text{Female}|\text{Long hair}) = \frac{2}{3}$

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

Bayes Theorem

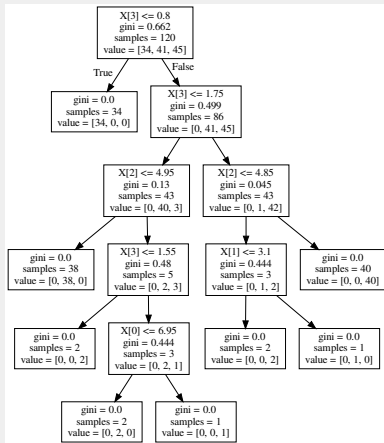
$$P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{P(B|A) \times P(A)}{P(B)}$$

SUPPORT VECTOR MACHINES (SVM)



- Goal: to draw a line to separate groups of data
- Ideal good line: maximising the distance 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.

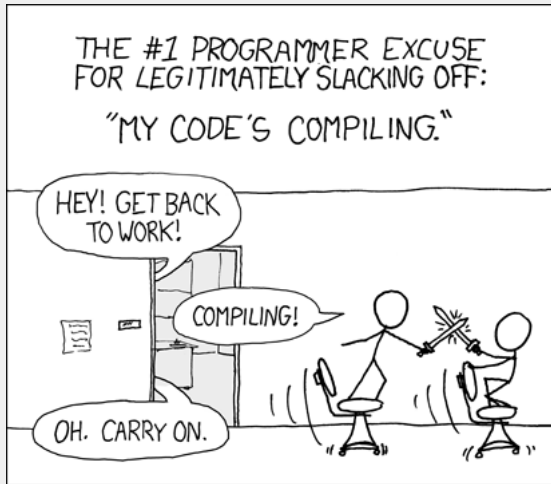


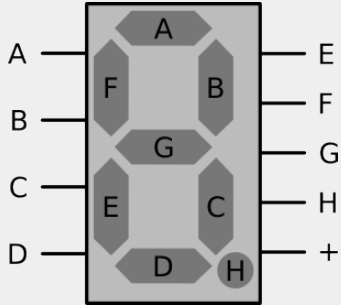
Figure: xkcd - Compiling



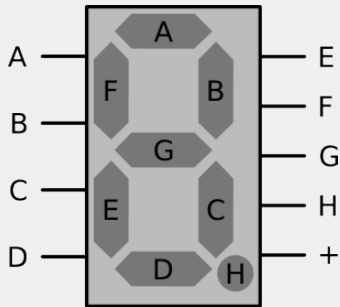
Figure: xkcd - Compiling

PROBLEMS FOR MACHINE LEARNING

7-SEGMENT DISPLAY

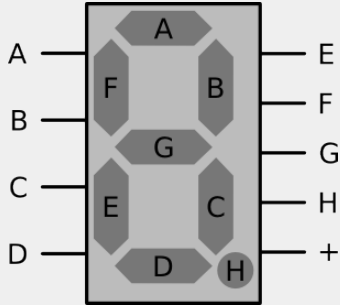


7-SEGMENT DISPLAY



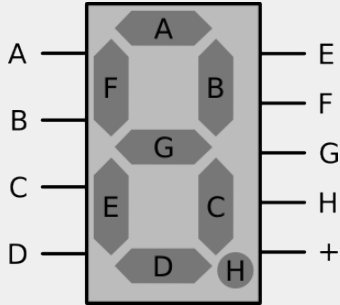
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- This is a 7-segment display.
- It consists of a bulb labelled from A-G that could form a number.

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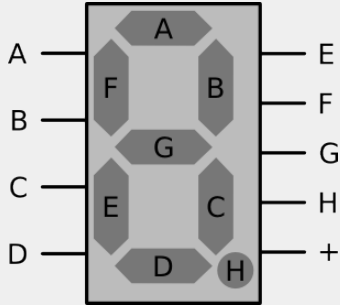


- This is a 7-segment display.
- It consists of a bulb labelled from A-G that could form a number.

Problem

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

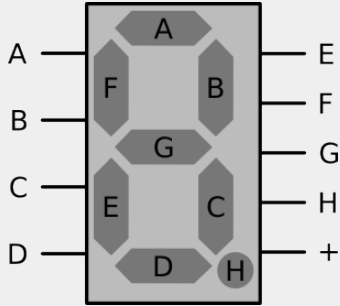
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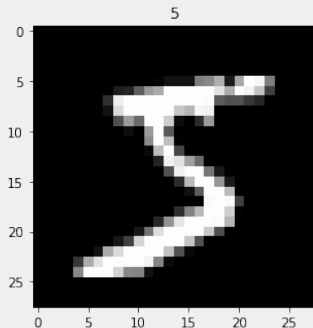


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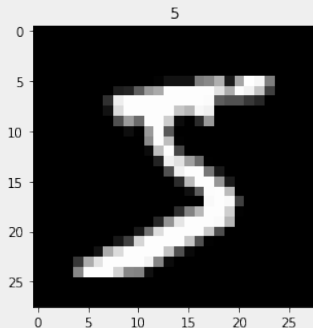
Not only yes, but *easily* yes!

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



Problem

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



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



MNIST DATASET



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

MNIST DATASET



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 - ▶ Later to be viewed as a vector of 784 dimensions

MNIST DATASET



- 28*28 pixel images of handwritten numbers (0-9)
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- 60,000 training images

MNIST DATASET



- 28*28 pixel images of handwritten numbers (0-9)
 - ▶ Later to be viewed as a vector of 784 dimensions
- 60,000 training images
- 10,000 testing images

- 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**
- Good results with k -NN were achieved.
(k -NN w/ non-linear deformation (P2DHMDM), preprocessed with shiftable edges, results into 0.52% error rate.)

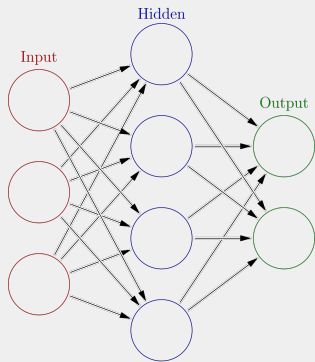
- Training: Slow as hell.

Trust me, I've tried.

- Good results with SVM were achieved.
(Virtual SVM, deg-9 poly, 2-pixel jittered with deskewing preprocessing results into 0.56% error rate.)

NEURAL NETWORKS

ARTIFICIAL NEURAL NETWORKS (ANN)



This seems complex, right? We'll get start a little by little...

Figure: Neural network
(Courtesy: Glosser.ca from
Wikimedia Commons)

NEURONS

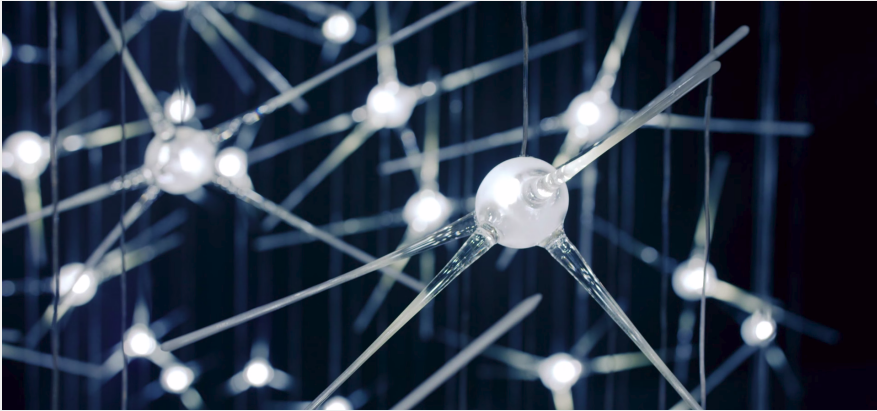


Figure: "Neurons" chandelier installed at Princh Mahidol Hall, Nakhon Pathom, Thailand
(Courtesy: LASVIT's promotion video)

NEURON

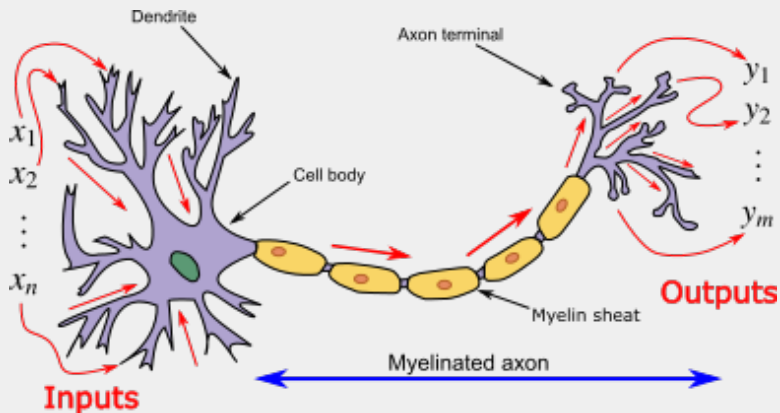
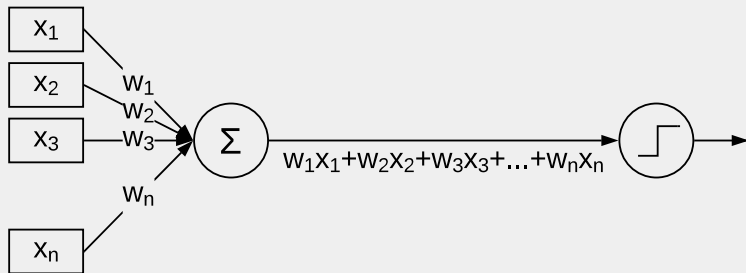


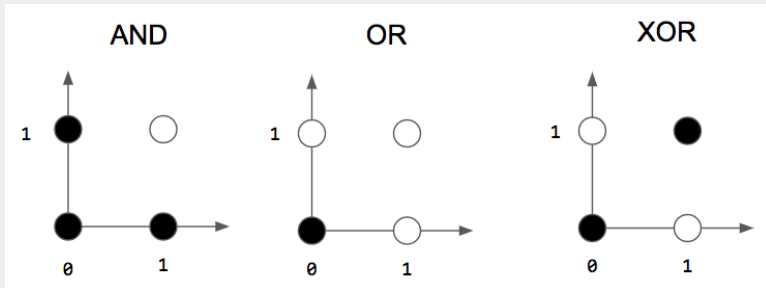
Figure: Neuron (Courtesy: Egm4313.s12 from Wikimedia Commons)

PERCEPTRON



- **Inputs** consisting of n inputs from $x_1, x_2 \dots$ to x_n .
- **Weights** of each inputs, namely w_1, w_2, \dots, w_n
- **Summation** of all the weighted inputs $\Sigma = w_1x_1 + w_2x_2 + \dots + w_nx_n$
- **Activation function** in either the form of $\Sigma > k$ or $\Sigma < k$ (*nonlinear*)

LOGIC GATES WITH PERCEPTRON



AND gate

- $w_1 = 1$
- $w_2 = 1$
- $\Sigma = 1x_1 + 1x_2$
- $f : \Sigma \geq 2$

OR gate

- $w_1 = 1$
- $w_2 = 1$
- $\Sigma = 1x_1 + 1x_2$
- $f : \Sigma \geq 1$

XOR gate

Why can't XOR gate be created using a perceptron?

LINEARLY SEPARABLE PROBLEM

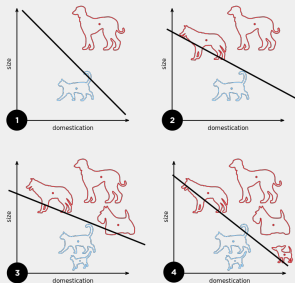


Figure: Linearly Separable Problem
(Courtesy: Elizabeth Goodspeed
from Wikimedia Commons)

- 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?

ARTIFICIAL NEURAL NETWORKS

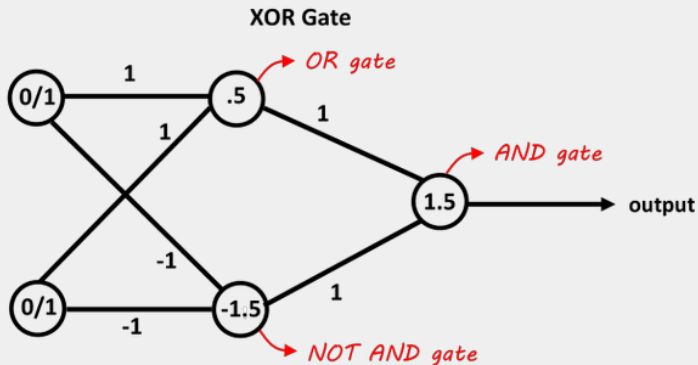


Figure: XOR gate with Perceptrons connected together (Courtesy: Parth Udawant)

How are the weights of each dendrites (inputs) are automatically adjusted?

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- ▶ Initiate weights randomly
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(Seriously, one day it will converge. There exists a mathematical proof)

YOUR NEXT STEP INTO MACHINE LEARNING

COURSES IN KU-CPE TO BE TAKEN

- Engineering Mathematics I
- Discrete Mathematics and Linear Algebra
- Artificial Intelligence/Machine Learning

For practical use, go ahead with...

- Google's Machine Learning Crash Course
- Udemy's Machine Learning (UD120)

Thanks!

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sirakorn.l@ku.th