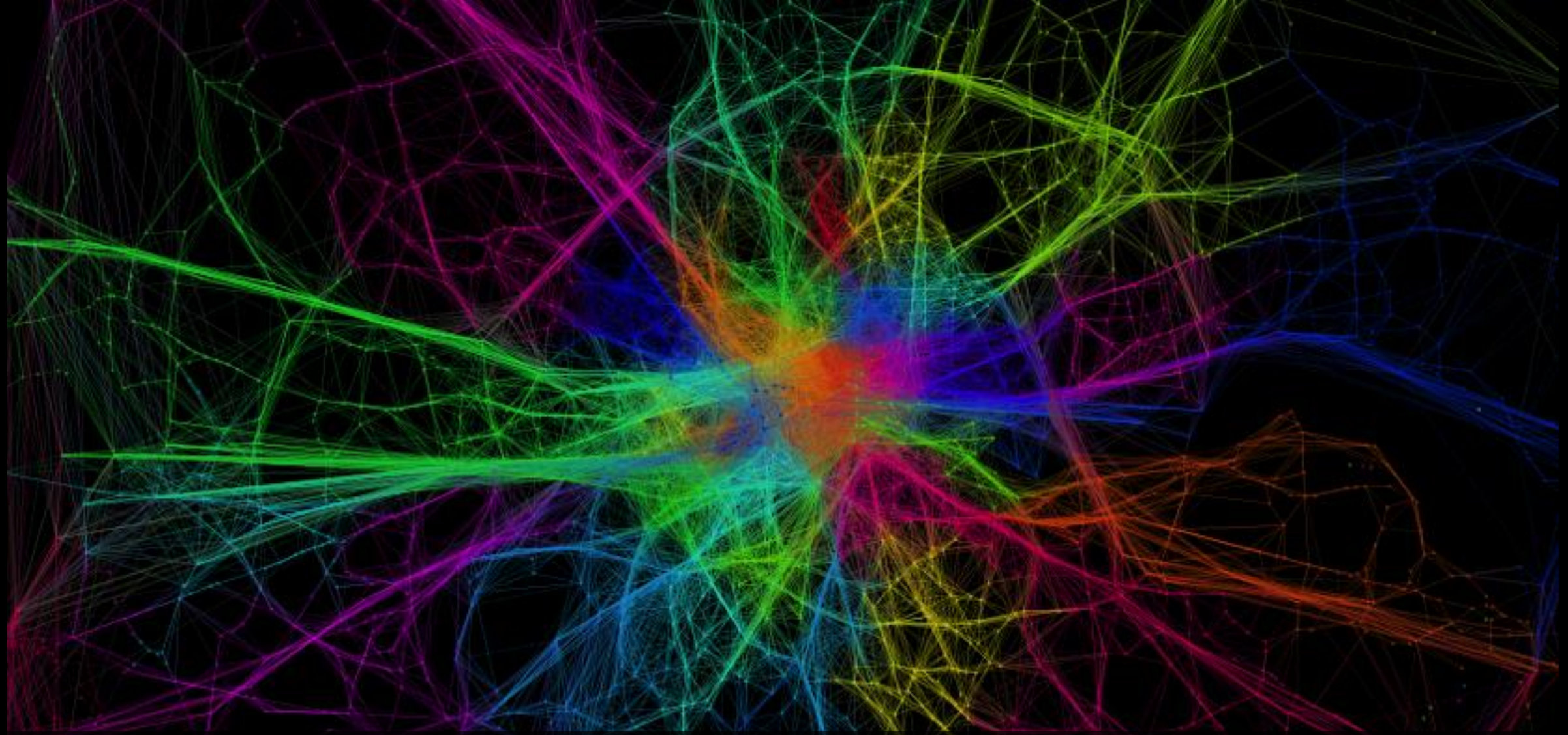


# Introduction to machine learning

CASA0006: Data Science for Spatial Systems

Huanfa Chen

# CASA0006

1. Introduction to Module
2. Supervised Machine Learning
3. Tree-based Methods
4. Analysis Workflow
5. Artificial Neural Networks
6. Panel Regression
7. Dimensionality Reduction
8. Spatial Clustering
9. Difference in Difference
10. Regression Discontinuity

# Objectives

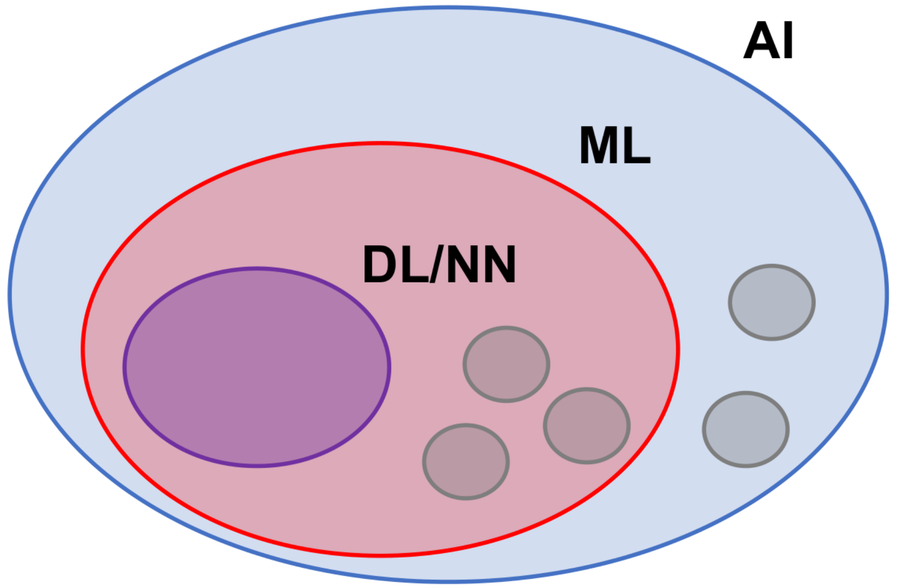
- Learn the basics and classification of machine learning
- Understand the differences between statistical methods and machine learning
- Understand several important theorems in machine learning and data science

# Introduction to ML

# ML is a subset of AI

- Machine learning (decision tree, random forest, k-means, etc.)
- Deep learning (deep neural networks)
- Others AI tools: graphical models, symbolic AI

- In this module, we don’t distinguish ML/DL and consider NN as part of ML.



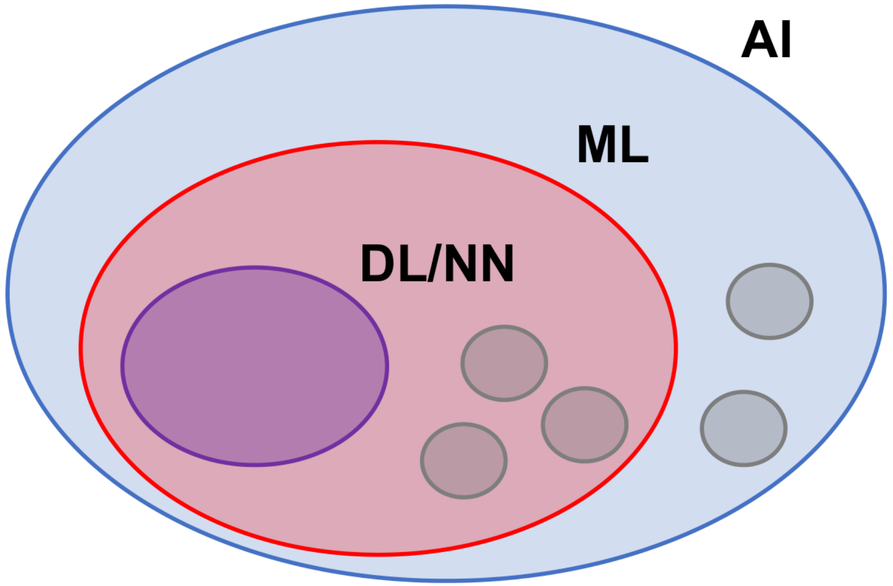
# Definition of ML

*Arthur Samuel (1959)*

- (Machine learning is the) field of study that gives computers the ability to learn without being explicitly programmed.

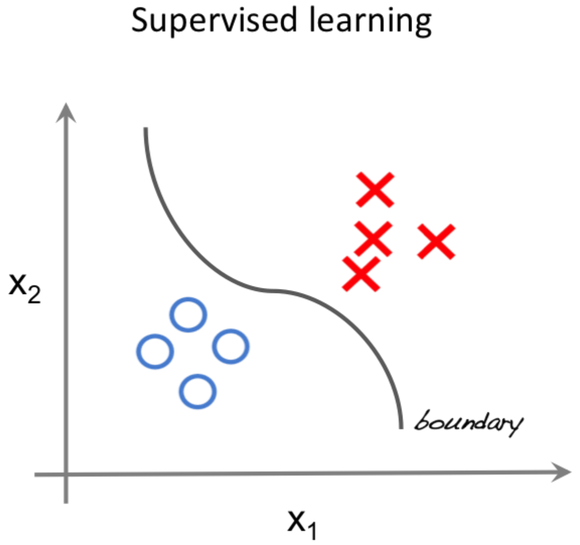
*Tom Mitchell (1997)*

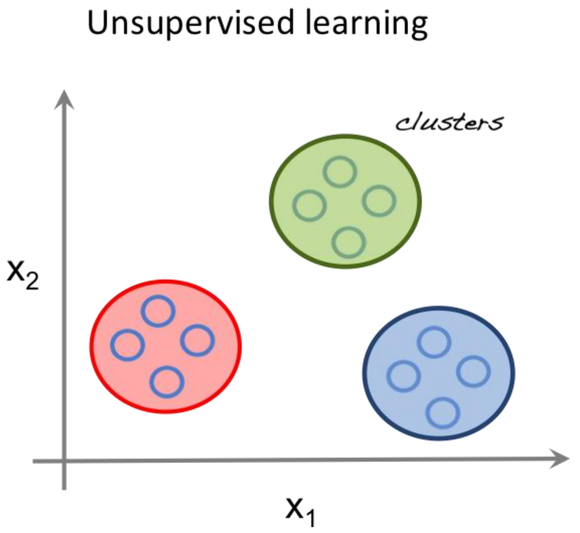
- A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E.



# Three types of ML

- Supervised: Learn to predict output given input (with labelled data).
- Unsupervised: Discover internal representation/structure of input (without labelled data).
- Reinforcement: Learn actions to maximise payoff (via interactions with the environment).



# Three types of ML

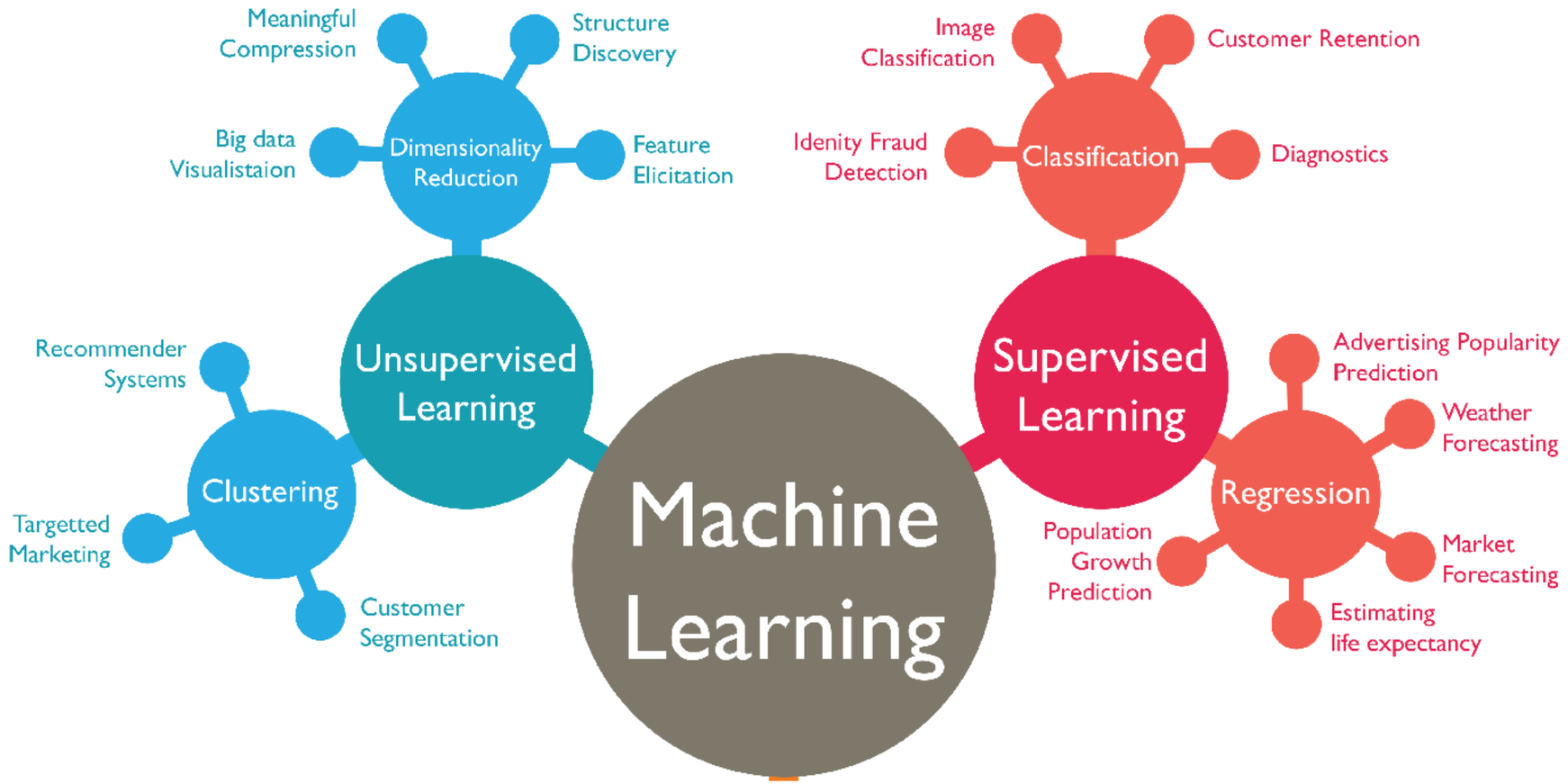



Image Source: https://www.slideshare.net/awahid/big-data-and-machine-learning-for-businesses

# Go to **www.menti.com** and use the code ~~**2515 0560**~~

Putting linear regression into the framework of ML. Which type of ML will linear regression fall into?

- ○ Supervised
- ○ Unsupervised
- ○ Reinforcement

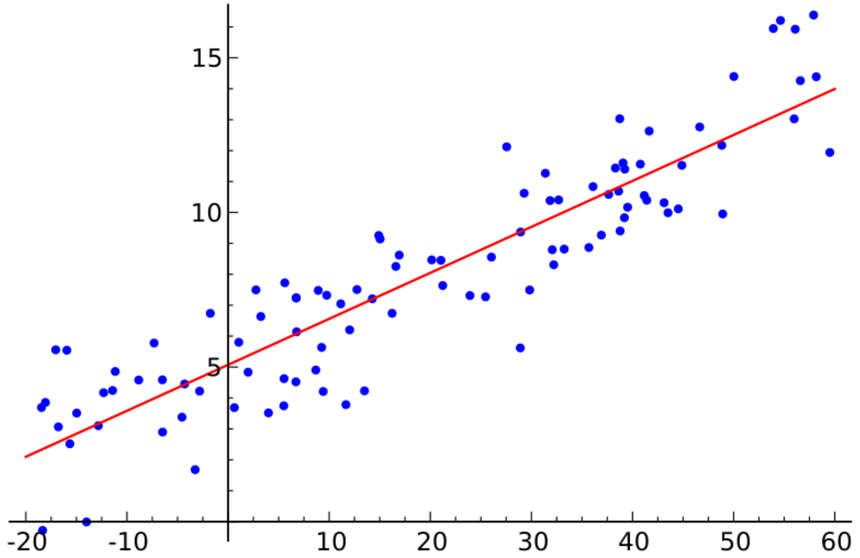
Submit

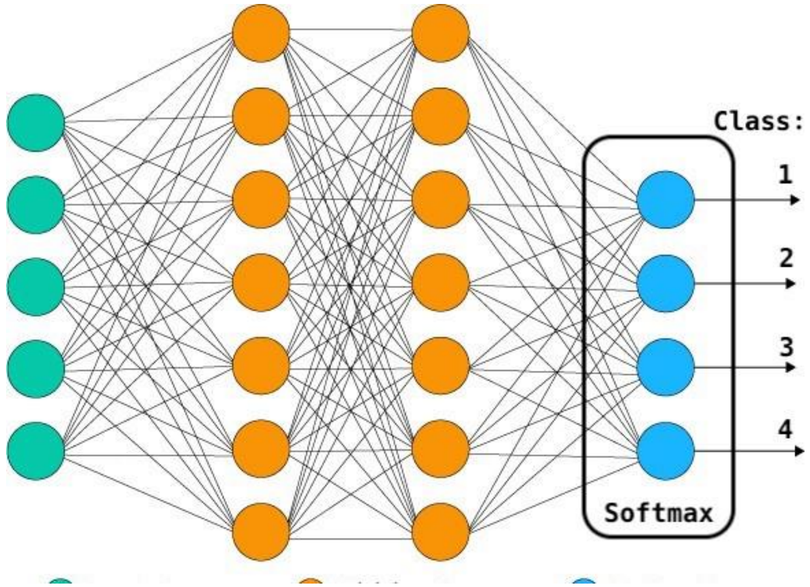
# Statistics versus ML

# More specific questions

- Given advanced and emerging ML algorithms, are statistical models such as linear regression still important?

- What are the differences between statistical models and ML?

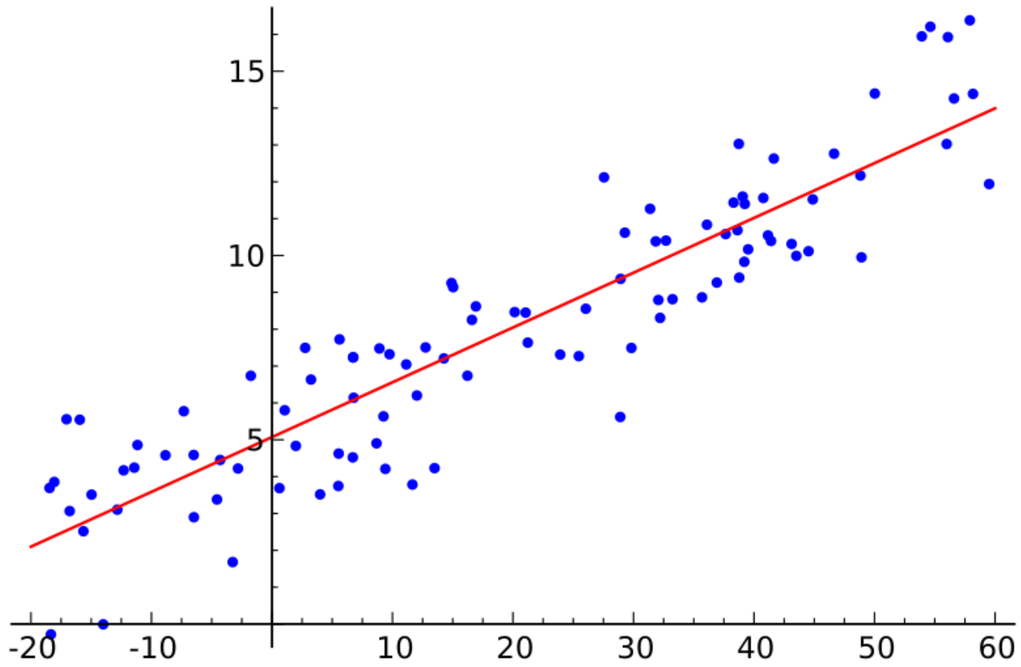


# Statistics

$$\hat{y}_i = \sum_k \beta_k x_{ik} + \beta_0$$

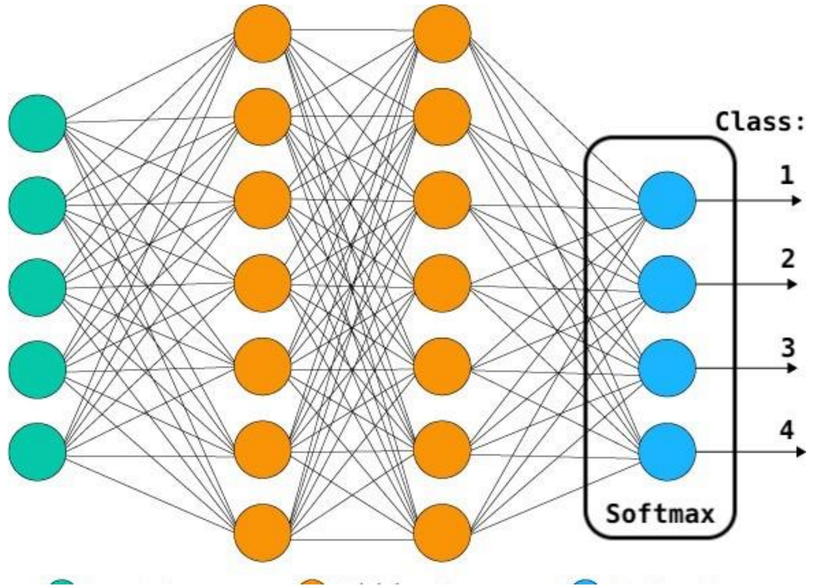
- Assumptions (Linear relationship, independent errors, normally distributed errors, equal variance of errors): need to test if assumptions hold true
- Need to check multicollinearity between variables
- Simple model structure
- Relatively low predictive accuracy, good interpretation



# Machine learning

$$y = f(x)$$

- Very few assumptions
- Complex model structure, difficult to understand why they works
- Require a lot of data
- High predictive accuracy and relatively low interpretation (black-box)



# Major difference: purposes

- Statistical models are more used to estimate the (causal) relationship between variables, esp in social and economic research

- Does smoking lead to lung cancer?
- Does family background affect the level of education?

- ML models are good for predictions, esp when the data size is huge and predictive performance is the priority

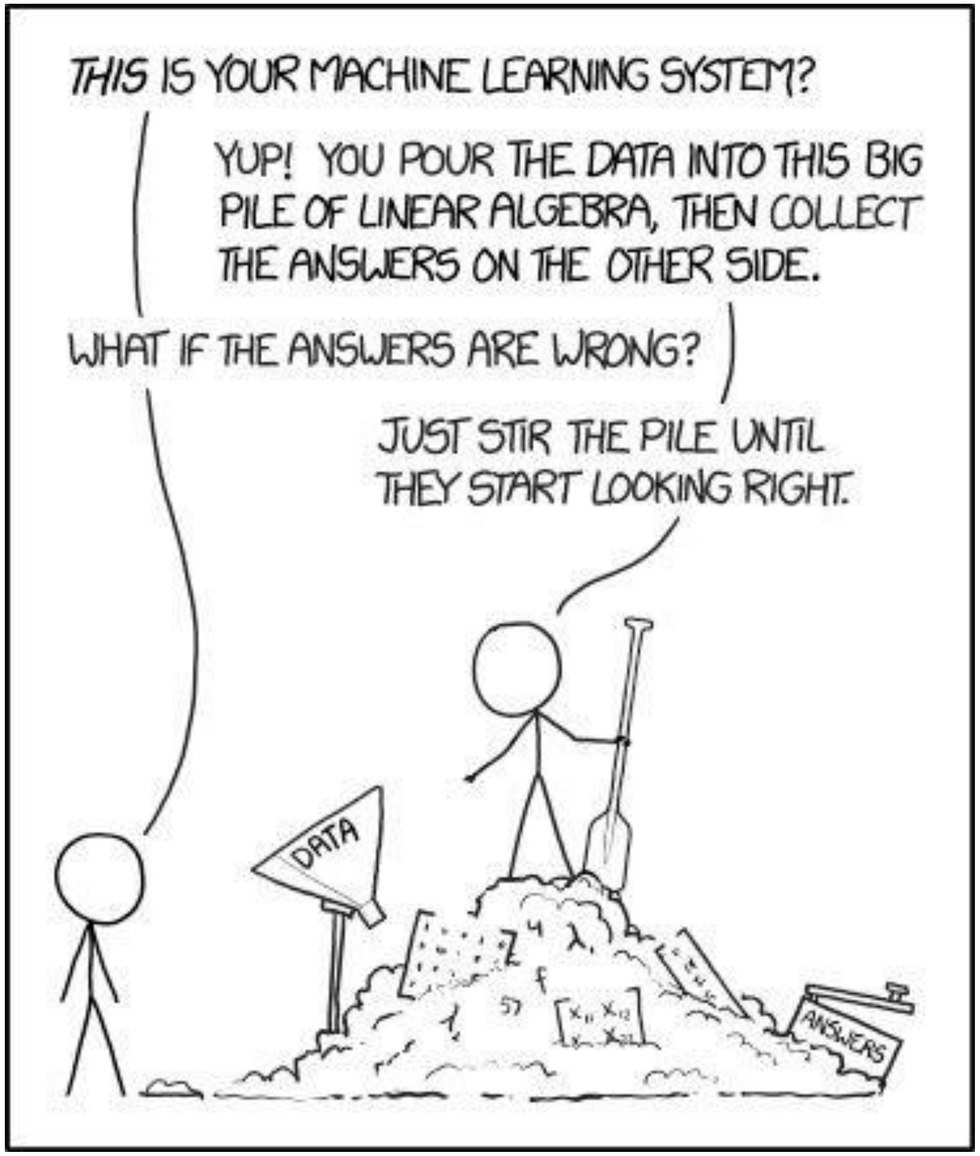
- What is tomorrow's weather like?
- Can we automatically classify emails into spam and non-spam?

Theorem 1:

Garbage in, garbage out (GIGO)

(*Data is the new Oil)*

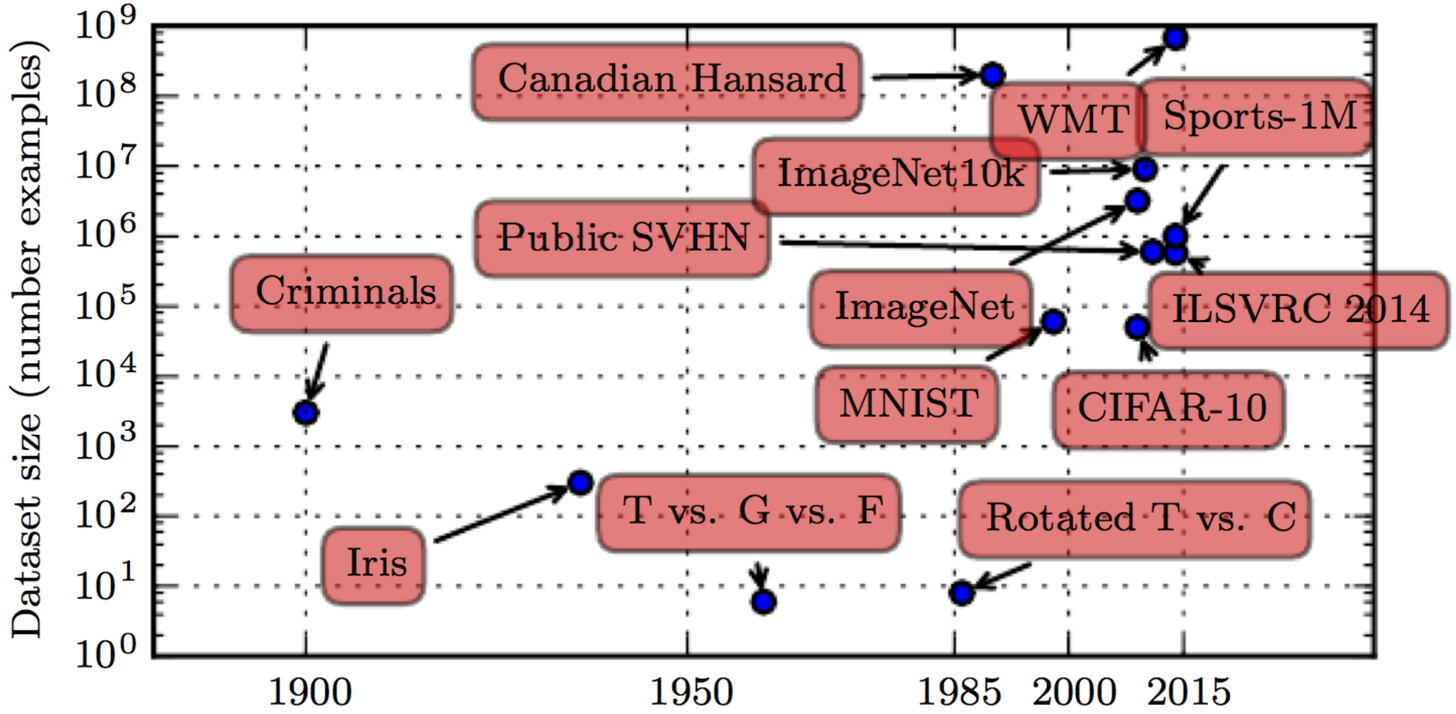
# Great algorithms + bad data = bad results




**Source: https://x.com/xschelling/status/954936528555429888**

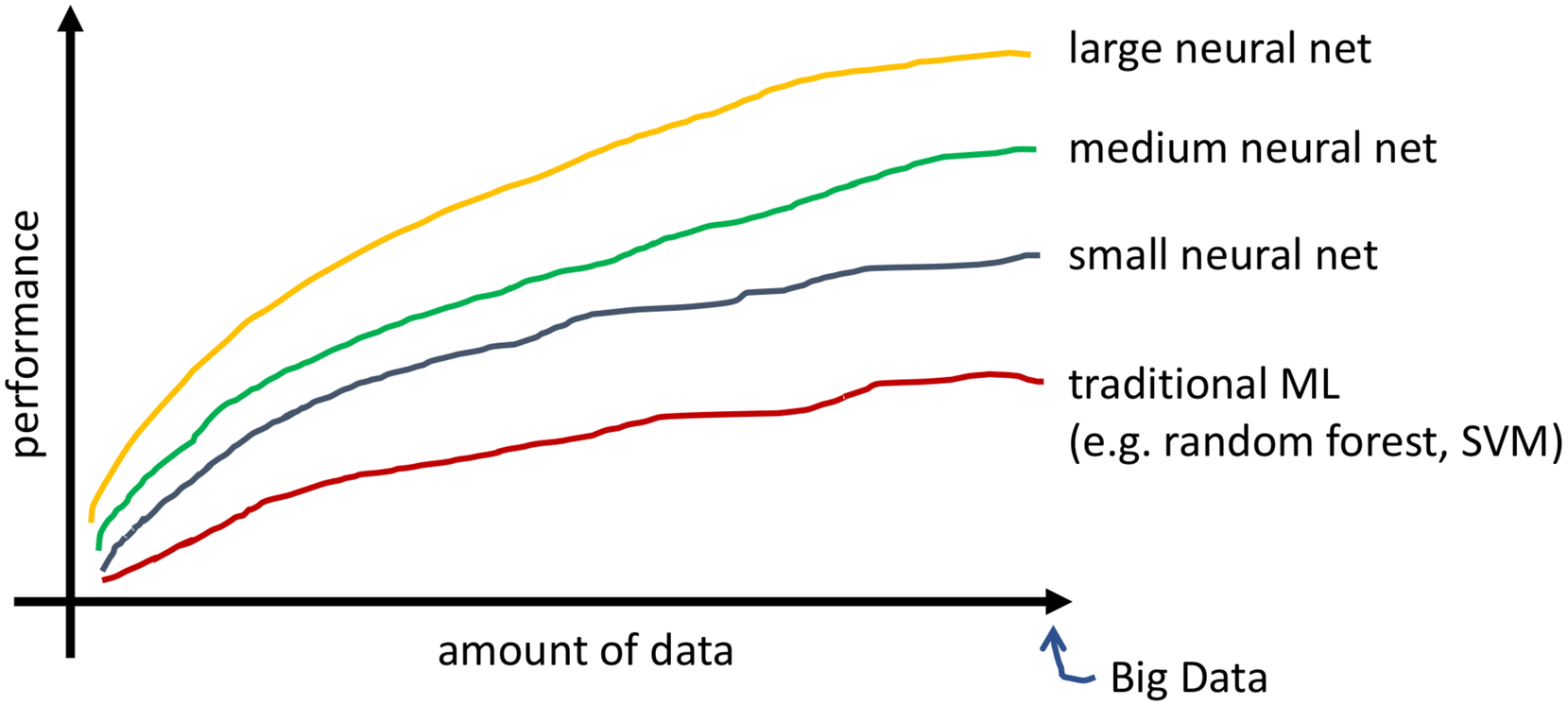
# Good data = large size + high quality

**Size of benchmark datasets**




**Source: https://www.deeplearningbook.org/**

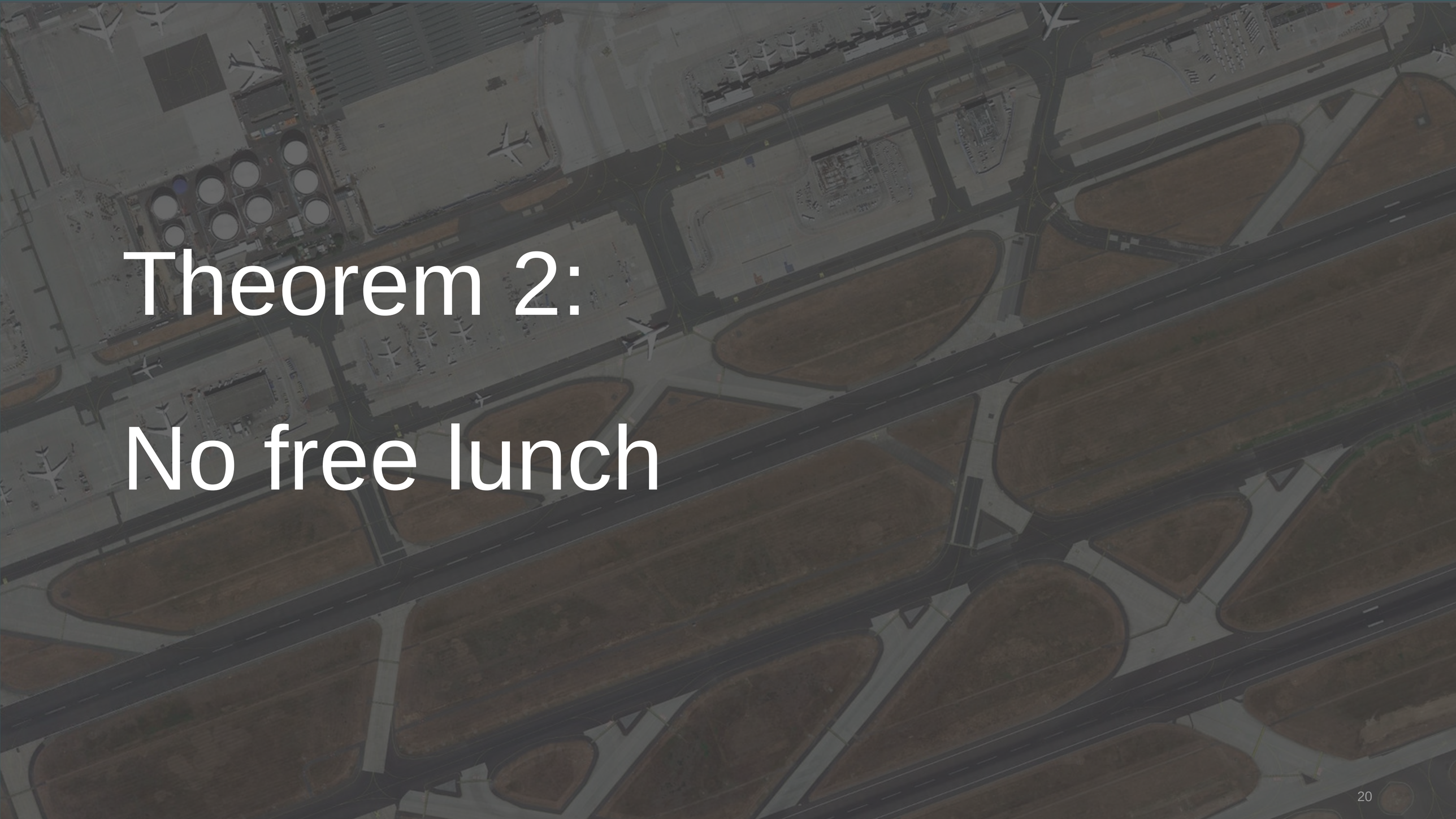
# The performance of ML/DL increases rapidly with the size of the data



# Feature engineering

- Using domain knowledge to extract and transform features from raw data, in order to improve the performance of ML algorithms
  - Removing noisy or erroneous data
  - Dealing with missing data
  - Generating new features by combining existing ones

- Example: how can locations be used in ML methods for predicting house price?
  - Long/lat;
  - Distance to POIs (train stations/schools);
  - Using adjacency matrix
- *Features* in ML are same as characteristics, properties, attributes, explanatory variables.

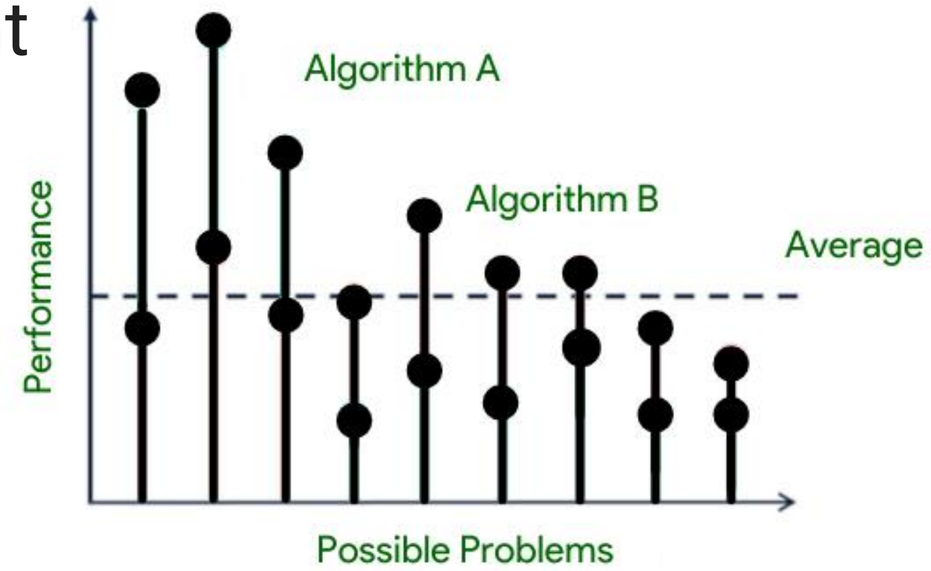


# Theorem 2:

# No free lunch

# Sorry, no free lunch ….

- Essentially, all algorithms are equivalent when performance is averaged over all possible problems.
- There is no a priori model that is guaranteed to work best on all problems.
- Therefore, it is a matter of validating models empirically




Wolpert, 1996, The lack of a priori distinctions between learning algorithms
Image source: https://www.geeksforgeeks.org/what-is-no-free-lunch-theorem/

# Tree models vs. NN

- Which model is more competitive? Depending on the data type
- For tabular data, tree models have higher predictive accuracy
- For image/text data, NNs are easier to use and have better performance

| size of house (square feet) | # of bedrooms | price (1000$) |
|---|---|---|
| 523 | 1 | 115 |
| 645 | 1 | 0.001 |
| 708 | unknown | 210 |
| 1034 | 3 | unknown |
| unknown | 4 | 355 |
| 2545 | unknown | 440 |

**Tabular data**

I read the news today, oh boy
About a lucky man who made the grade
And though the news was rather sad
Well, I just had to laugh
I saw the photograph

He blew his mind out in a car
He didn't notice that the lights had changed
A crowd of people stood and stared
They'd seen his face before
Nobody was really sure if he was from the House of Lords

**Unstructured data**

# Summary

- There are three types of ML
- The difference between supervised and unsupervised ML
- The difference between statistical models and ML. Choose the tool according to the purpose and domain
- Good data is more important than algorithms
- No free lunch

# Workshop

- Weekly quiz on Moodle
- Python notebook