UNSUPERVISED LEARNING AND REINFORCEMENT LEARNING

Introduction to Machine Learning, Artificial Intelligence and Deep Learning
Session 06

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2

Unsupervised Learning

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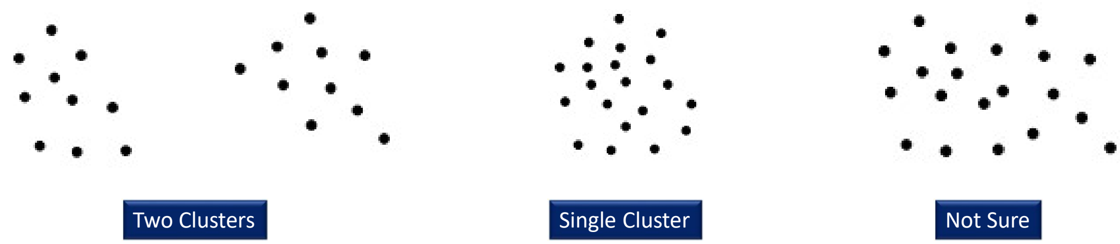
3

Clusters



Unsupervised learning uses procedures that attempt to find natural partitions of patterns.

4

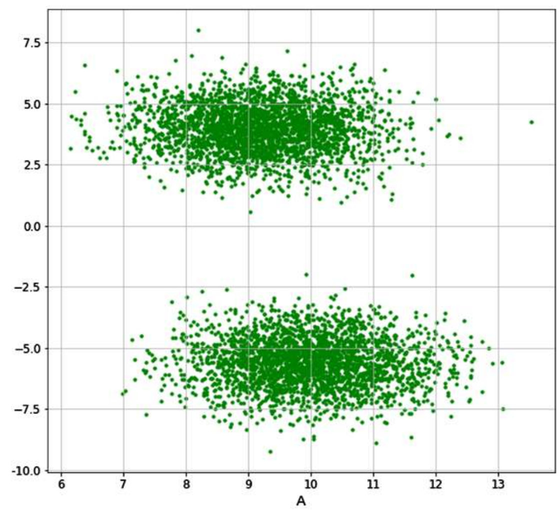
What is Clustering Good for

- **Market segmentation** - group customers into different market segments
- **Social network analysis** - Facebook "smartlists“
- **Organizing computer clusters** and data centers for network layout and location
- **Astronomical data analysis** - Understanding galaxy formation

5

K-means Algorithm

- Randomly allocate two points as the cluster centroids
- There can be as many cluster centroids as needed (K cluster centroids, in fact)
- Consider data as shown



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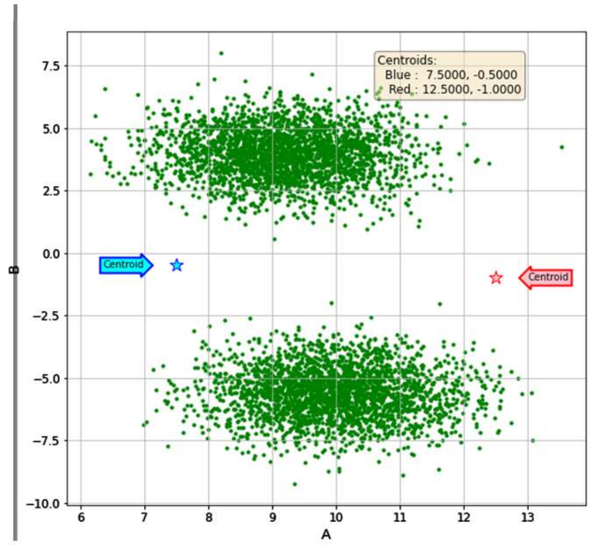
Iterations

- Our data has two groups
- Consider centroids for two groups arbitrarily
- Calculate Euclidean distance of each point from the two centroid.
- Allocate the point to centroid with minimum distance



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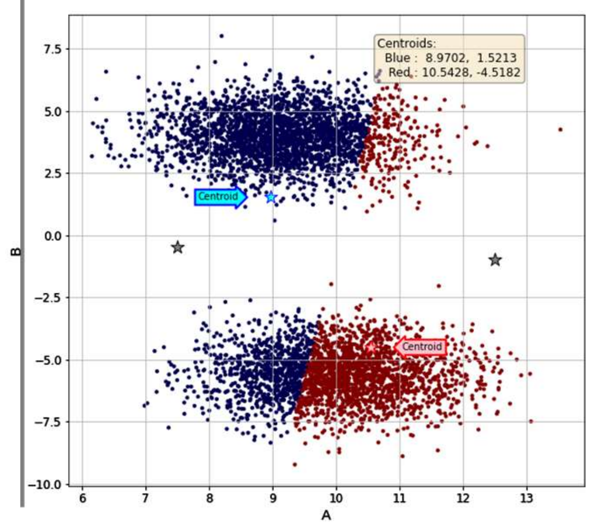
Iterations

- After allotment, calculate coordinates of centroid of each of the group
- Move the centroid to new location.



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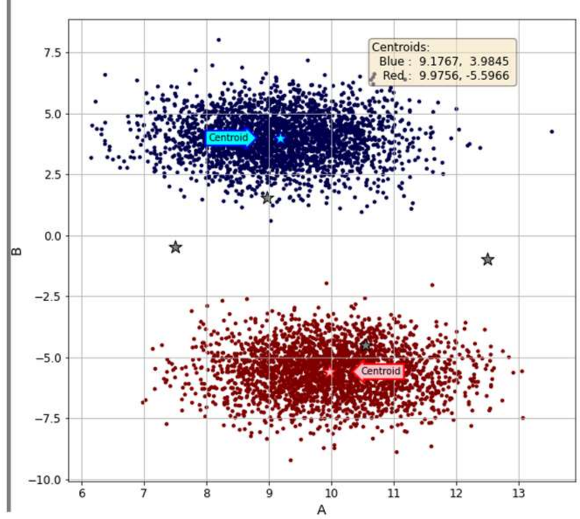
Iterations

- Once again calculate Euclidean distance of each point from the two centroid
- Allot the points to closest centroid
- And we have identified the clusters



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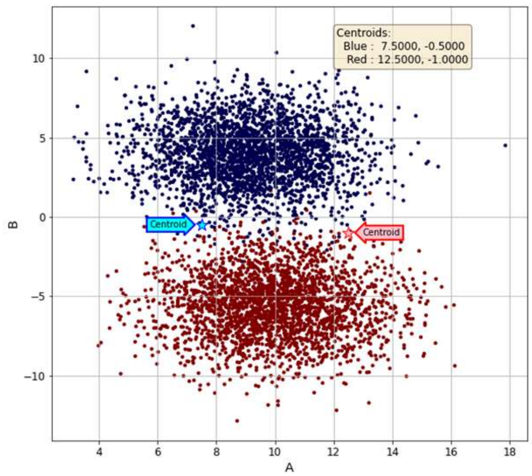
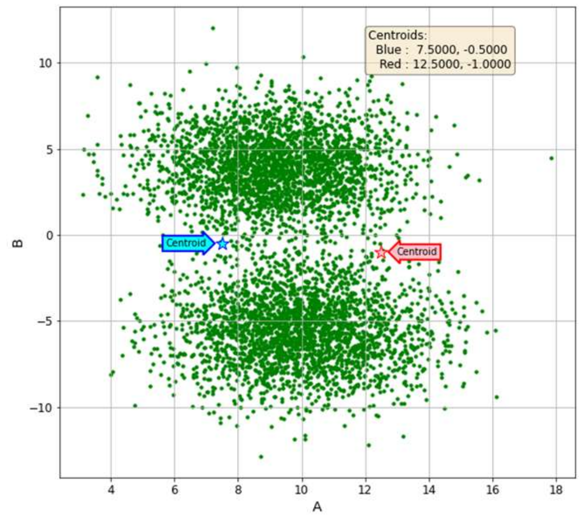
Iterations

- Another example with not so obvious separation





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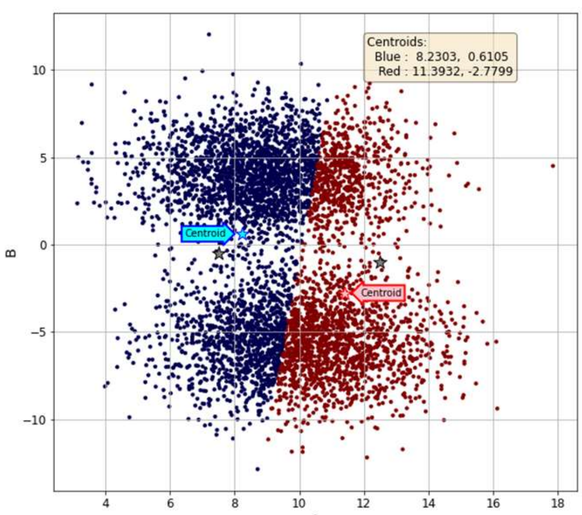
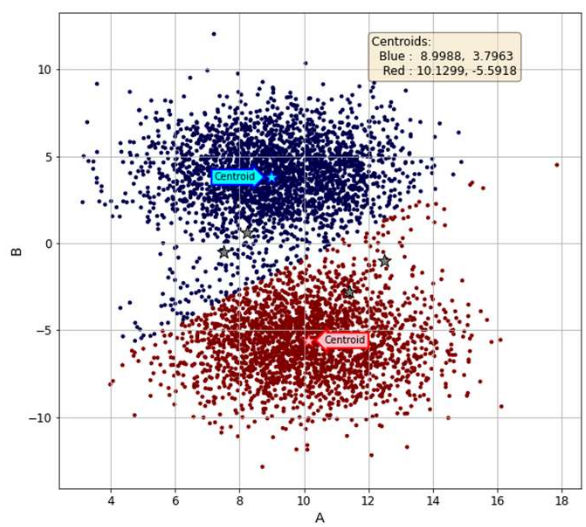
10

Iteration 1 and 2





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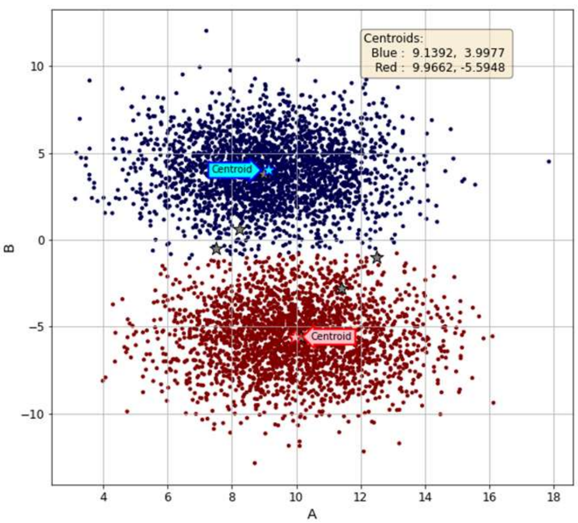
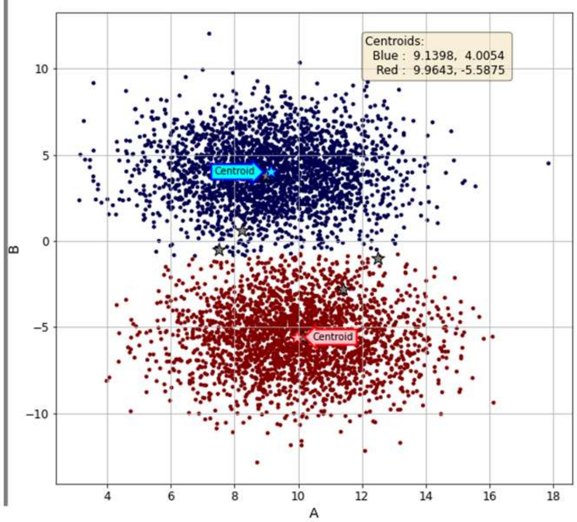
11

Iteration 3 and 4





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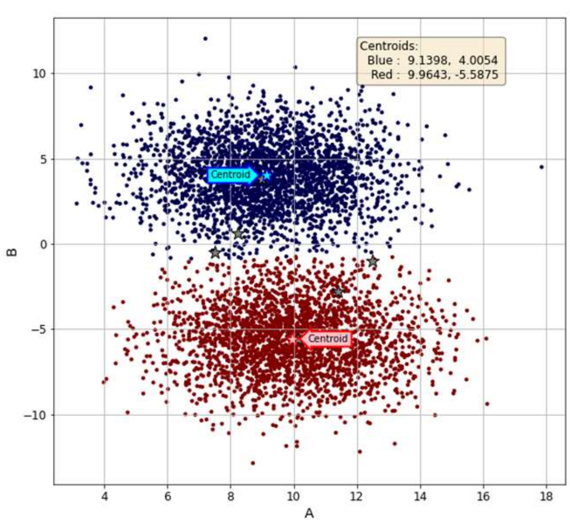
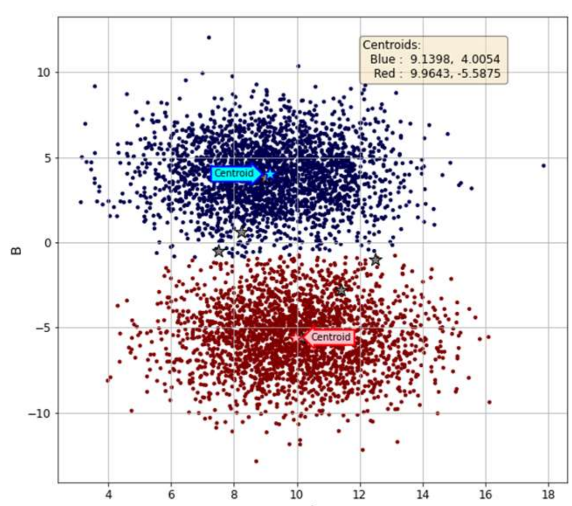
Iteration s 4 and 5





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Clustering Distance Measures

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Dissimilarity or Distance matrix

- Classification of observations into groups requires
  - Some methods for computing the **distance** or
  - The (dis)**similarity** between each pair of observations
- Distance measures is a critical step in clustering.
- Wide varieties methods available
- Method of calculations of the similarity of two elements (x, y) influences the shape of the clusters

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Methods for Distance Measures

- The classical methods for distance measures :
  - Euclidean Distances
  - Manhattan Distances
  - Minkowski Distances
  - Hamming Distance
- Others:
  - Pearson correlation distance
  - Eisen cosine correlation distance (Eisen et al., 1998)
  - Spearman correlation distance
  - Kendall correlation distance
- Pearson correlation analysis is the most commonly used method.
  - Also known as a parametric correlation which depends on the distribution of the data
- Kendall and Spearman correlations are non-parametric
  - Used to perform rank-based correlation analysis

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Euclidean distance

- Most common method of distance measurement
- The distance between two real-valued vectors : x, y ∈ $\mathbb{R}$
- Used for calculating the distance between numerical values – Floats or integers.

$$d_{euc}(x, y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

- If columns have values with differing scales:
  - normalize or standardize the numerical values to prevent one column prevail over other

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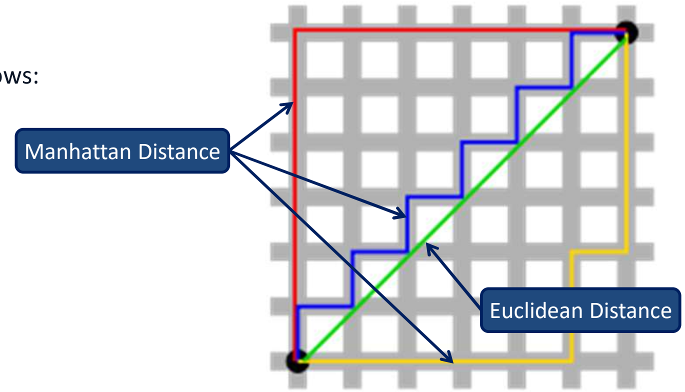
Manhattan Distance

- Names allude to the grid layout of most streets on the island of Manhattan
- Causes the shortest path a car could take between two intersections to have length equal to the intersections' distance
- Manhattan Distance is calculated as follows:

$$d_m(x, y) = \sum_{i=1}^{n} |x_i - y_i|$$



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18

Minkowski Distances

- Both Euclidean and Manhattan Distances are special case of Minkowski Distance
- The formula for Minkowski Distance is given as:

$$\mathrm{d_m}(x, y) = (\sum_{i=1}^{n} (x_i - y_i)^p)^{1/p}$$

  - For p = 1 and p = 2, it becomes Manhattan and Euclidean Distances

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Hamming Distance

- Measures the similarity between two strings of the same length.
- The number of positions at which the corresponding characters are different

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Pearson correlation distance

- A correlation-based distances
- Widely used for gene expression data analyses
- Correlation-based distance is defined by subtracting the correlation coefficient from 1
- Pearson correlation measures the degree of a linear relationship between two profiles
- It is calculated as follows:

$$d_{cor}(x, y) = 1 - \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 . \sum_{i=1}^{n} (y_i - \bar{y})^2}}$$

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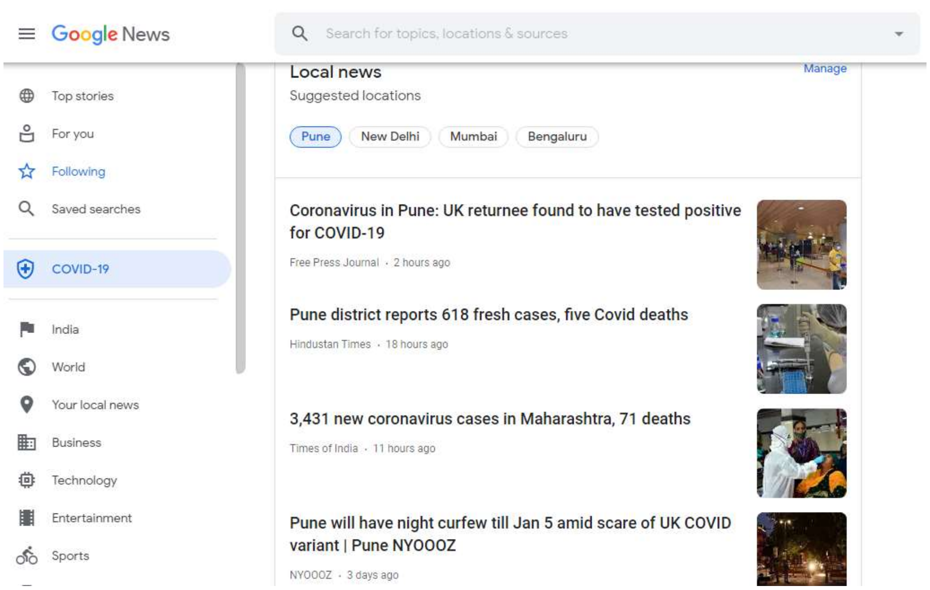
21

Clustering Examples

22

News Clustering



23

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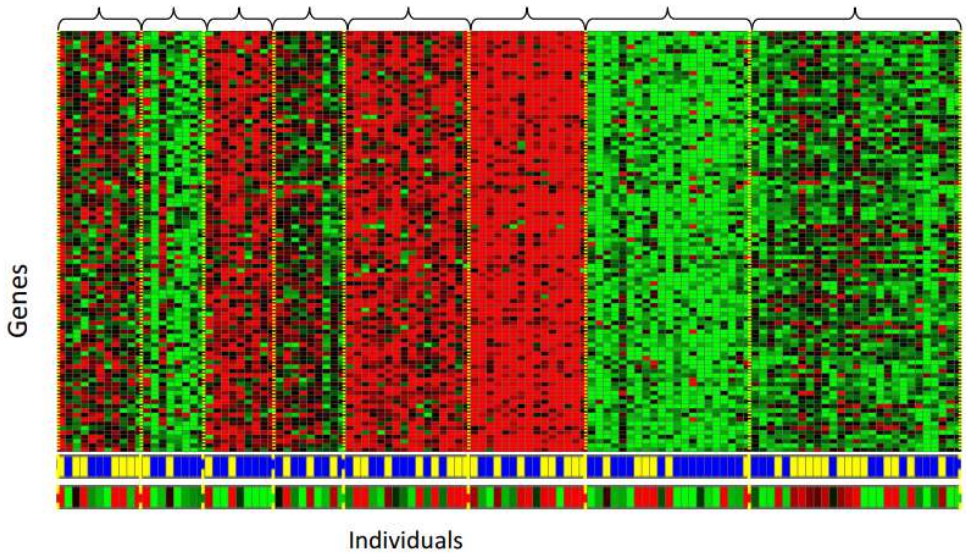
- Genomics application: group individuals by genetic similarity



24

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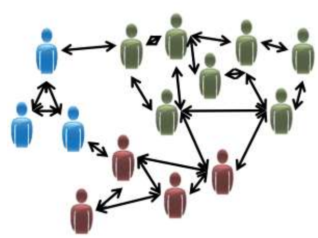
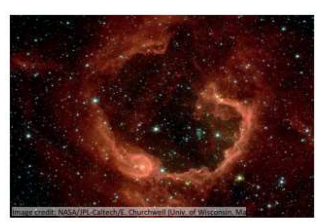
Organize computing clusters



Social network analysis

Market segmentation

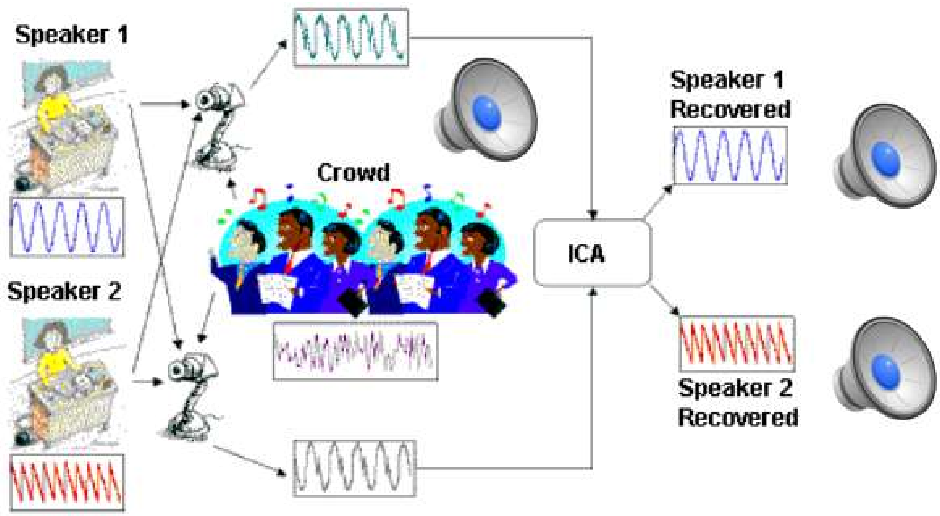


Astronomical data analysis

25

Unsupervised Learning

- Independent component analysis – separate a combined signal into its original sources



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26

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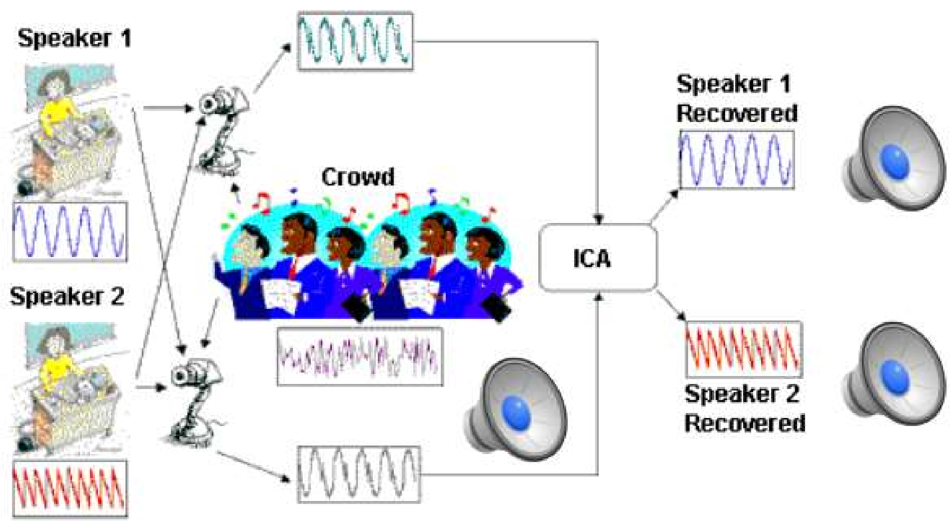
- Independent component analysis – separate a combined signal into its original sources



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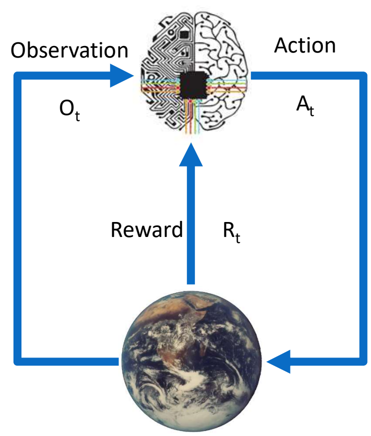
Reinforcement Learning

- Reinforcement Learning
  - Given a sequence of states and actions with (delayed) rewards, output a policy
  - Policy is a mapping from states $\Rightarrow$ actions that tells you what to do in a given state

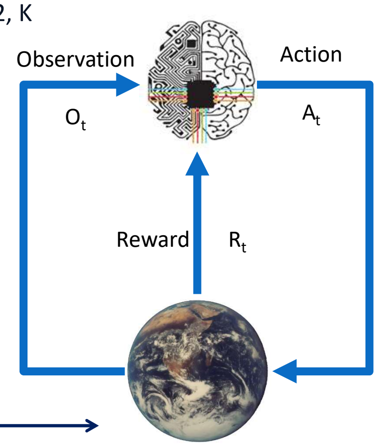
- Examples:
  - Credit assignment problem
  - Game playing
  - Robot in a maze
  - Balance a pole on your hand

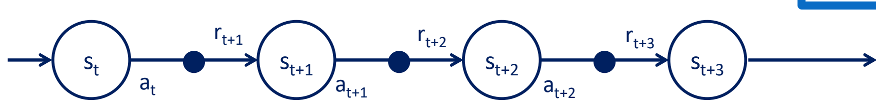


28

The Agent-Environment Interface

- Agent and environment interact at discrete time steps : t = 0, 1, 2, K
  - Agent observes state at step t: $s_t \in S$
  - Produces action at step t : $a_t \in A(s_t)$
  - Gets resulting reward : $r_{t+1} \in \Re$
  - And resulting next state : s_{t+1}





29

Examples of Reinforcement Learning

- Fly stunt maneuvers in a helicopter
- Defeat the world champion at Backgammon
- Manage an investment portfolio
- Control a power station
- Make a humanoid robot walk
- Play many different Atari games better than humans

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Fly stunt maneuvers in a helicopter

Stanford Computer Scientists have developed an artificial intelligence system that enables robotic helicopters to teach themselves to fly difficult stunts by watching other helicopters perform the same maneuvers. The technique is known as "apprenticeship learning." The result is an autonomous helicopter than can fly dazzling stunts on its own.

https://youtu.be/M-QUkgk3HyE

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Game Over: Kasparov and the Machine (trailer)

The documentary "Game Over: Kasparov and the Machine", about the 1997 chess match between Garry Kasparov and Deep Blue, the IBM computer. It also features Yasser Seirawan, Anatoly Karpov and others.

https://youtu.be/y9UMt-8gfW8

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DeepMind Made A Superhuman AI For 57 Atari Games!

https://youtu.be/dJ4rWhpAGFI

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Automated Cargo Wharf Yangshan, Shanghai

- World's biggest automated cargo wharf, the fourth phase of the Yangshan deep-water port started operation on Sunday.
- The core technology of the robotic port was developed independently by China.
- The forth phrase of Yangshan port takes up an area of 2.23 million square meters, whose coastline stretches as long as 2,350 meters. It consists of two 70,000 dead-weight tonnage (DWT) berths and five 50,000 DWT berths.

- https://youtu.be/IzOeAGAu60k

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Evaluating Machine Learning techniques

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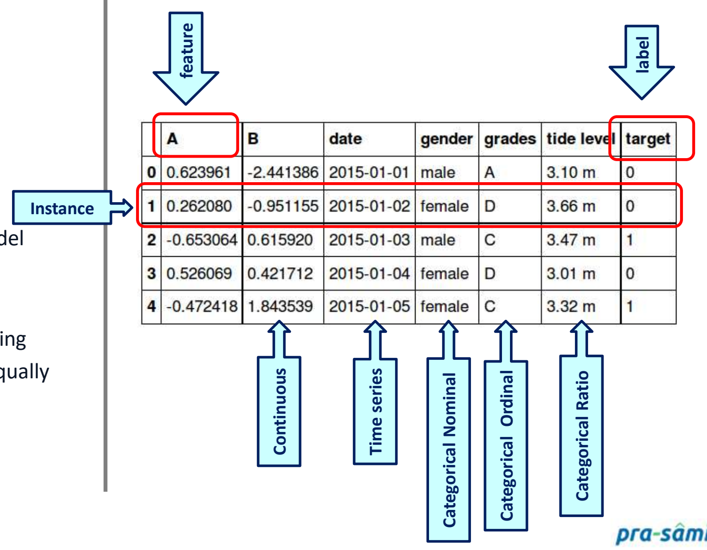
Common Terms

- Model
  - Collection of parameters you are trying to fit
- Data
- Instance
- Feature
  - Attributes of your data that will be used in prediction
- Labels
  - Value you are trying to predict with your model
- Categorical Data
  - Nominal : categorically discrete data
  - Ordinal : quantities that have a natural ordering
  - Interval : intervals between each value are equally split
  - Ratio: interval data with a natural zero point.
- Continuous Data



	A	B	date	gender	grades	tide level	target
0	0.623961	-2.441386	2015-01-01	male	A	3.10 m	0
1	0.262080	-0.951155	2015-01-02	female	D	3.66 m	0
2	-0.653064	0.615920	2015-01-03	male	C	3.47 m	1
3	0.526069	0.421712	2015-01-04	female	D	3.01 m	0
4	-0.472418	1.843539	2015-01-05	female	C	3.32 m	1

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36

How am I Doing?

- Ever suffered crash and burn in production?
- No one wants to see a failure in Prod
- How well a model will generalize to new cases?
  - Try it out on new cases
- It's better to test and validate in Dev

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Train – Test – Validate

- Split your data into Three sets
  - The training set (64 %)
  - The test set (16 %)
  - The Validation set (20 %)
- Train your model using the training set,
- Test it using the test set.
- The error rate on new cases(Test Set) is called the generalization error (or out-of-sample error),
- First indication of how well model will perform
- Case 1: Training Error High, Test Error High
  - Model is under fitting
- Case 2: Training Error Low, Test Error High
  - Model is over-fitting the training data.
- In train-test cycle, hyper parameters are tuned keeping test data as target
  - Model is **indirectly exposed** to test set

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Training Data and Test Data

- Same data cannot be used for Training and Testing
- Models give better results on seen data,
- Given huge number of epoch, it may even give perfect score
  - But would fail to predict anything useful on yet-unseen data
- In supervised machine learning hold out part of the available data as a test set and another part as validation set
- Train and tune the model on train + test set,
- Once tuning is complete, train the model on train + test data and validate on validation data
  - Remove random seed!
- Typical cross validation and grid search techniques are also clubbed in this process.
  - Be very careful not to leak information from test set to train set specially in cross validation
- Time series: No peeping into future

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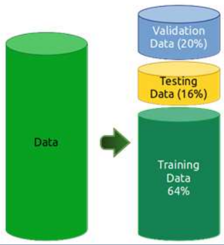
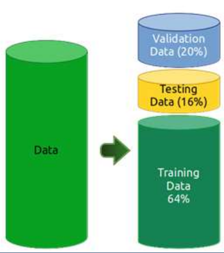
Data Split



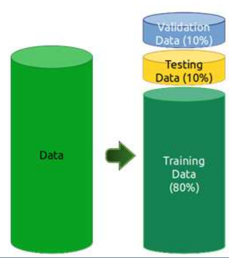
Up to 10,000 records

40

Data Split



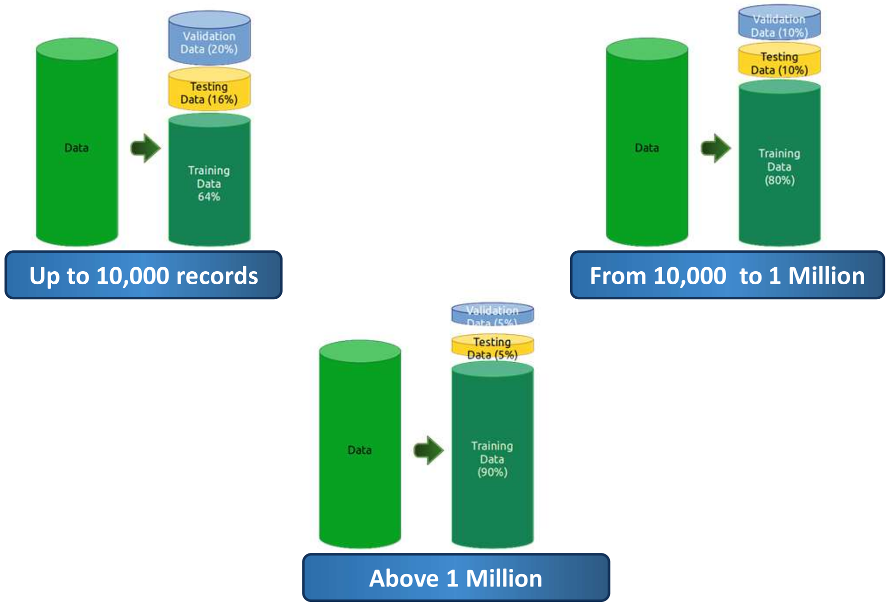
Up to 10,000 records



From 10,000 to 1 Million

41

Data Split



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Matching Distribution of Test and Train Data Sets

- Data Scientists are always looking for data
- There are plenty of curated datasets available
- Curated data sets are clean with sufficient features to explain a concept,
  - May not be suitable for real life application
  - Real data is dirty
- Example:
  - For object identification or image analytics, it is very common to perform web search and download picture
  - These pictures are of good resolution, taken under favorable lighting condition
  - After rollout, pictures taken by actual user may not be of similar quality
  - Resulting in significant drop of accuracy on real data

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Cross Validation

- Worried about more than $\frac{1}{3}$ data being used in test-validate
- The training set is split into complementary subsets,
  - Each model is trained against a different combination of these subsets
  - Test against the remaining parts.
  - Happy with the model type and hyper-parameters
  - Final model is trained using these hyper-parameters on the full training set,
  - The generalized error is measured on the validation set.

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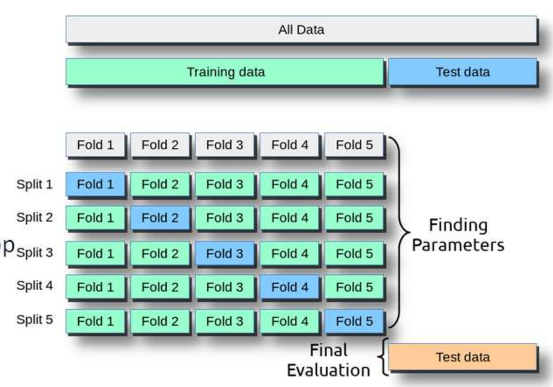
Cross-validation : Source Sklearn

- Partitioning the available data into three sets, drastically reduce the number of samples in each bucket
- Use cross validation to solve it.
  - The training set is split into k smaller sets
- Model is trained using multiple folds as training data;
- By rotation one fold is kept out
- Performance measure is average of the values in the loop
- Approach is computationally expensive,
- Recommended where data is limited



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Next Session

- Introduction
- AI vs ML vs Deep Learning
- MP Neuron
- Perceptron
- Single Layer Neural Network
- Overview of back propagation of errors

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47

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