Artificial Intelligence

Machine Learning (2)

Unsupervised Learning

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Junia ISEN / M1 / 2024-2025

Machine learning problems

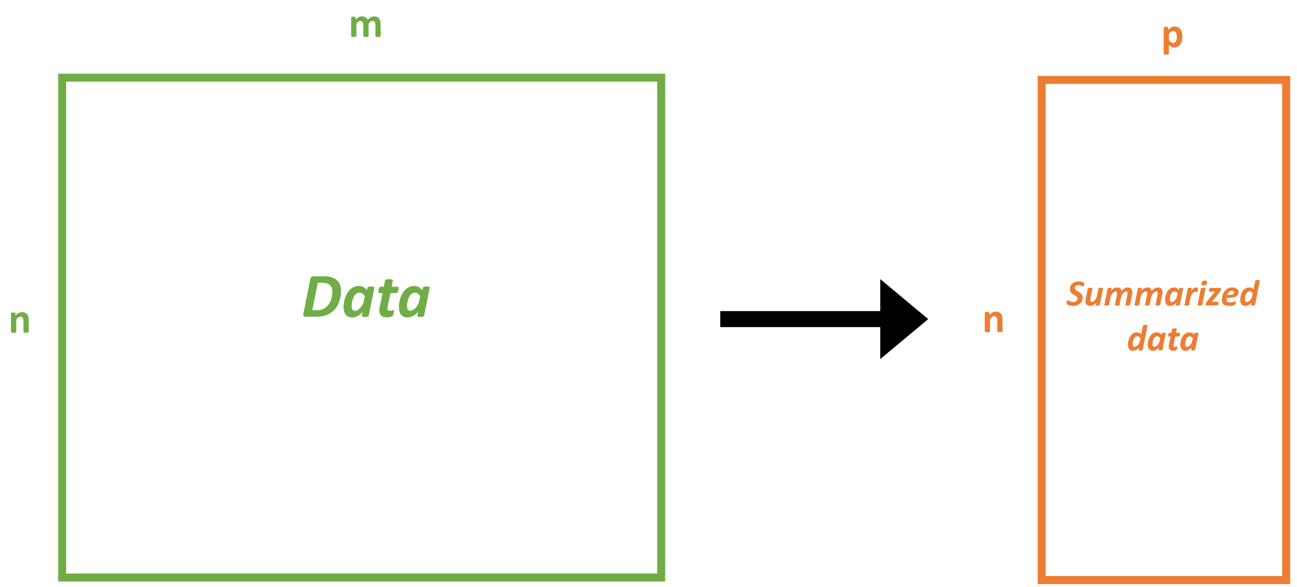
	Supervised learning	Unsupervised learning
Discrete data	**Classification**	**Clustering**
Continuous data	**Regression**	**Dimensionality reduction**

Dimensionality Reduction

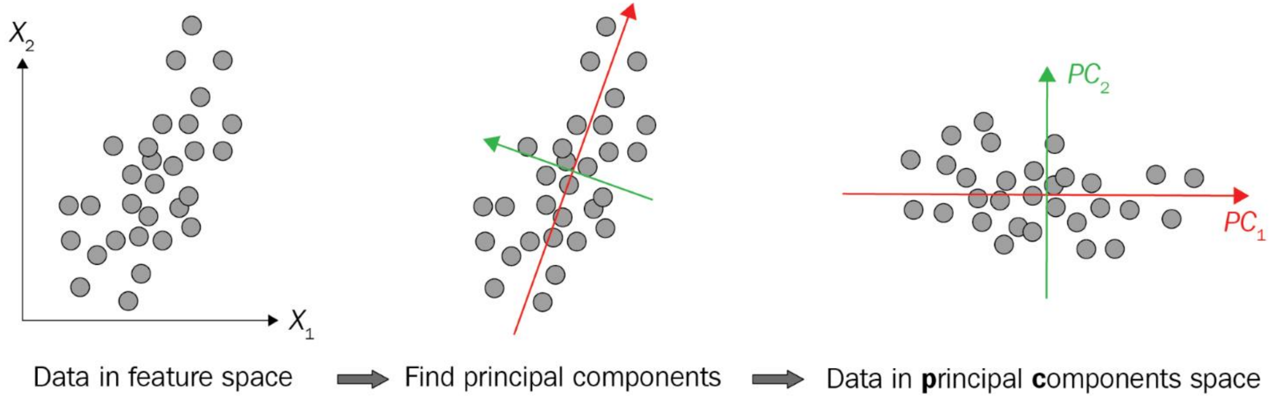
- summarization of data (n examples) with many dimensions (m attributes) by a smaller set of (p) derived (synthetic, composite) dimension

Why ?

- Data compression (with less loss of information)
- Structure Discovery
- Reducing training time and cost
- Effective visualization

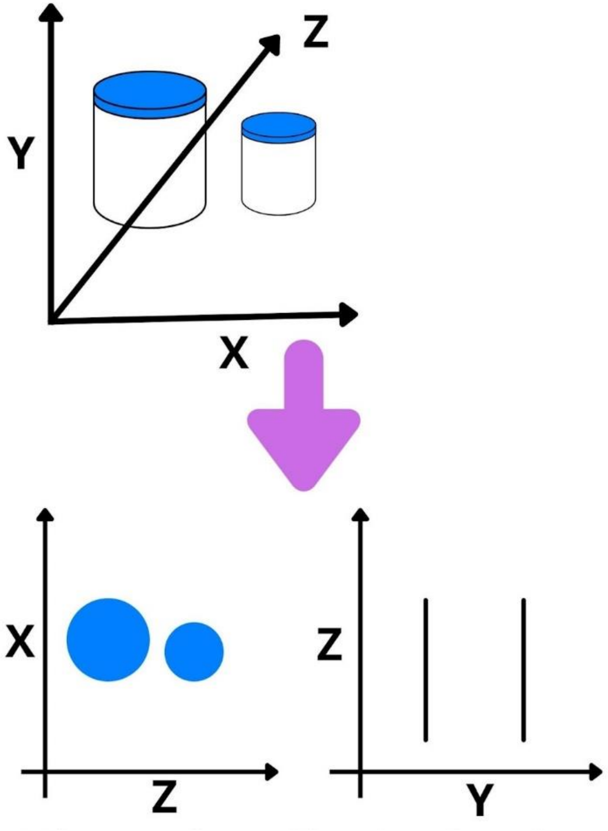


Dimensionality Reduction



Data in feature space → Find principal components → Data in **p**rincipal **c**omponents space

EXAMPLE 1



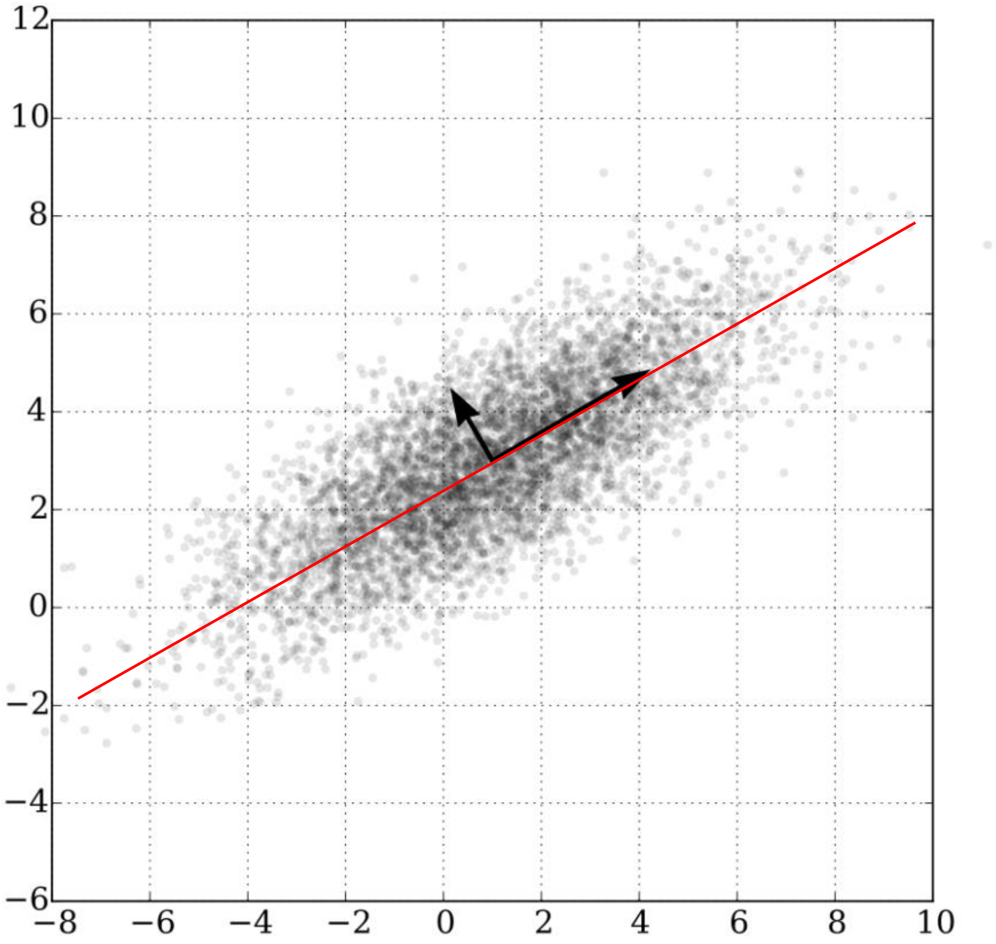
EXAMPLE 2

Dimensionality Reduction

- Multiple methods : **PCA,** ICA, LLE, Isomap, …
- Manifold Learning

Example :

https://scikit-learn.org/stable/auto_examples/manifold/plot_lle_digits.html



Tutorial

Apply PCA algorithm to IRIS dataset…

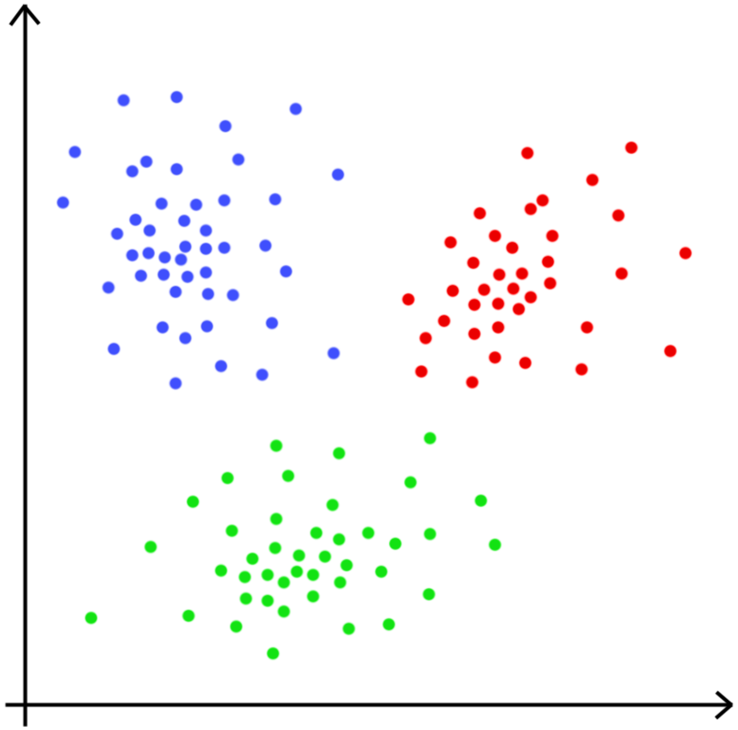
Machine learning problems

	Supervised learning	Unsupervised learning
Discrete data	**Classification**	**Clustering**
Continuous data	**Regression**	**Dimensionality reduction**

Intelligence is also the ability to recognize similar objects and group them!

The Problem of Clustering

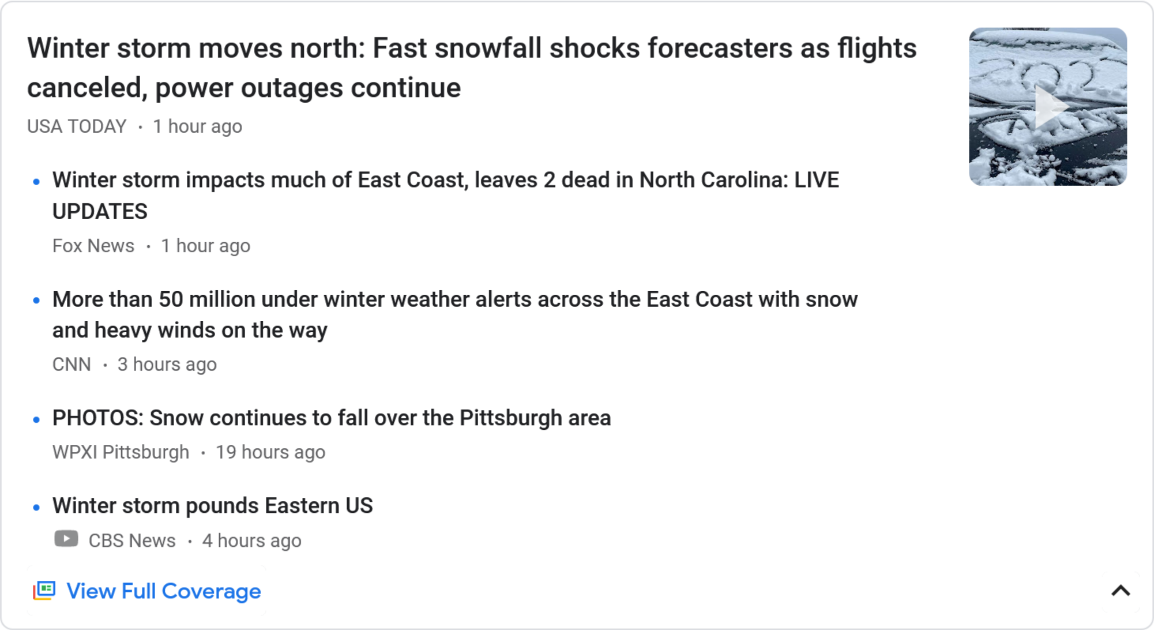
Given a set of unlabeled items (in n-dimensions), with a notion of distance between items, group the points into some number of clusters, so that members of a cluster are in some sense as nearby as possible.



Data without labels

Labeled Data

Example : Clustering news



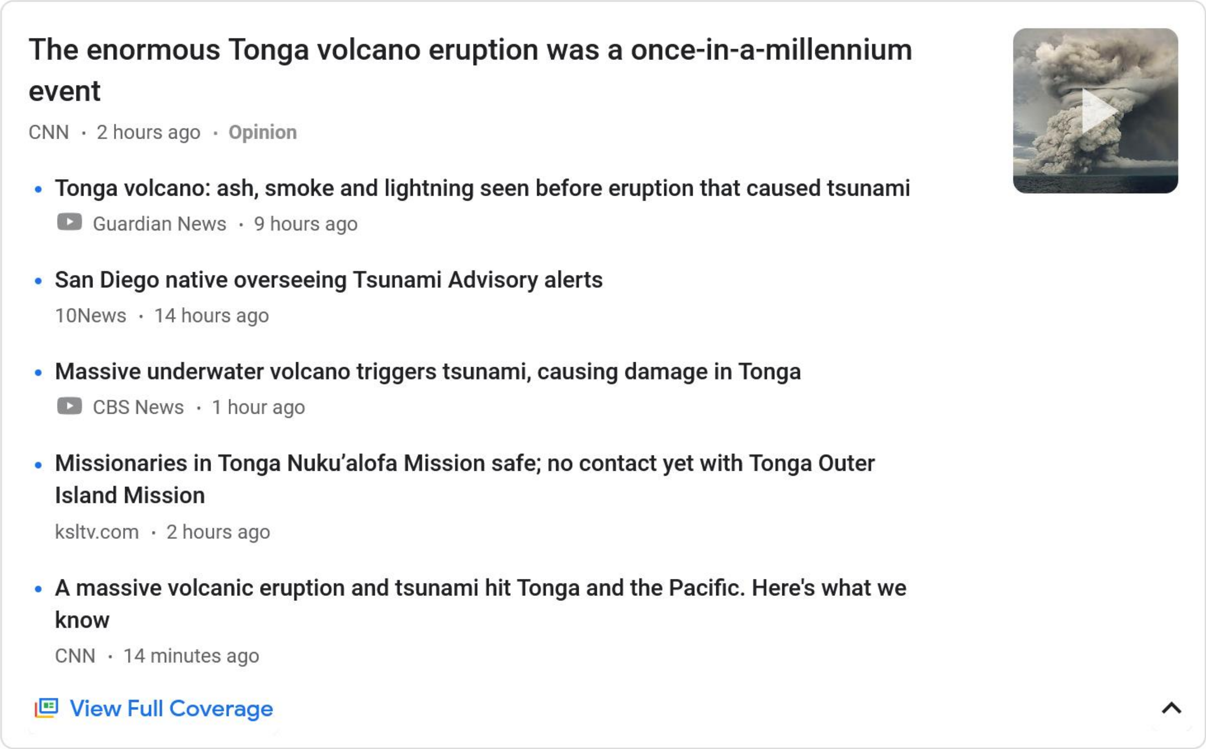
Winter storm moves north: Fast snowfall shocks forecasters as flights canceled, power outages continue

USA TODAY · 1 hour ago

- Winter storm impacts much of East Coast, leaves 2 dead in North Carolina: LIVE UPDATES
  Fox News · 1 hour ago
- More than 50 million under winter weather alerts across the East Coast with snow and heavy winds on the way
  CNN · 3 hours ago
- PHOTOS: Snow continues to fall over the Pittsburgh area
  WPXI Pittsburgh · 19 hours ago
- Winter storm pounds Eastern US
  CBS News · 4 hours ago

View Full Coverage

Winter Storm



The enormous Tonga volcano eruption was a once-in-a-millennium event

CNN · 2 hours ago · Opinion

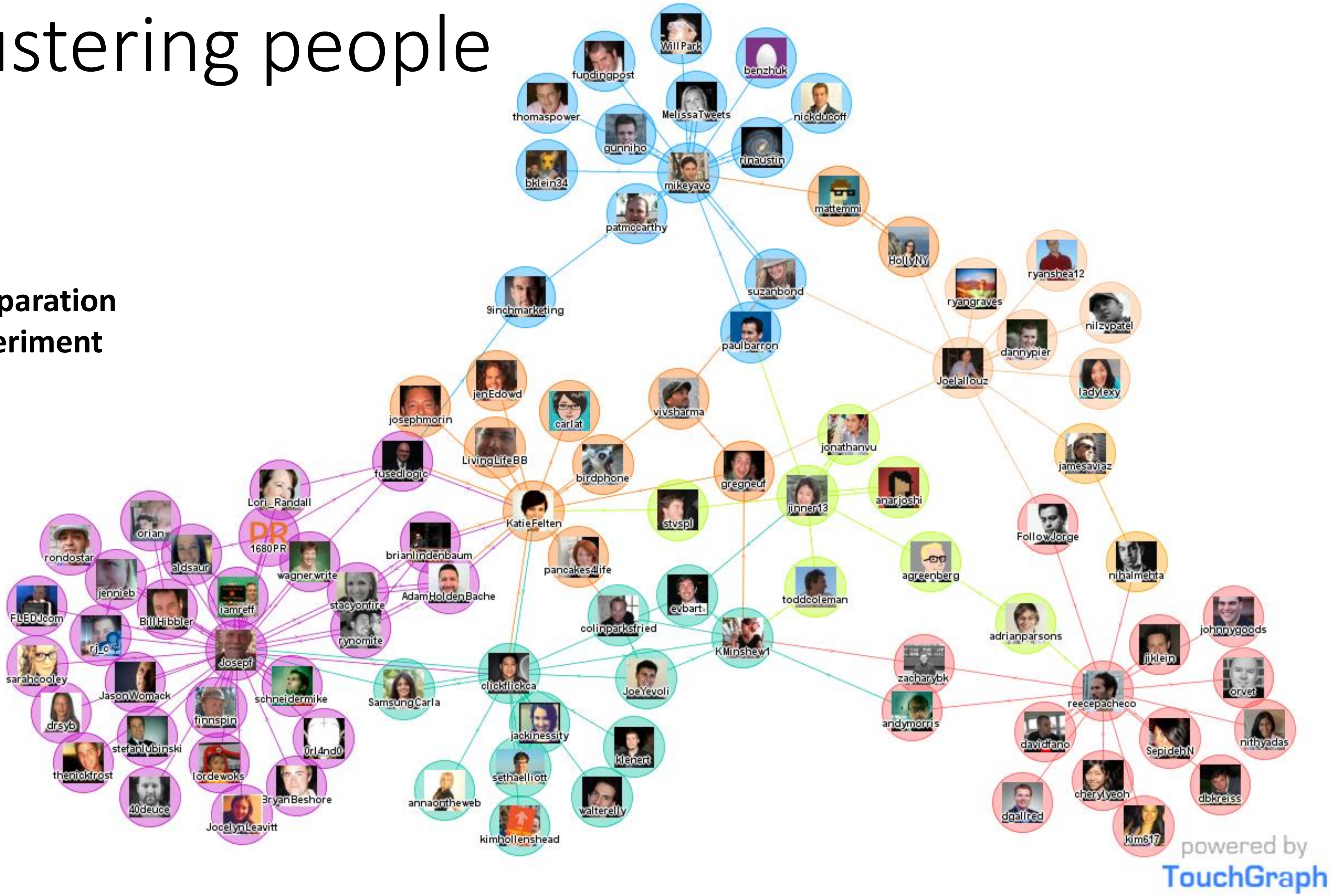
- Tonga volcano: ash, smoke and lightning seen before eruption that caused tsunami
  Guardian News · 9 hours ago
- San Diego native overseeing Tsunami Advisory alerts
  10News · 14 hours ago
- Massive underwater volcano triggers tsunami, causing damage in Tonga
  CBS News · 1 hour ago
- Missionaries in Tonga Nuku'alofa Mission safe; no contact yet with Tonga Outer Island Mission
  ksltv.com · 2 hours ago
- A massive volcanic eruption and tsunami hit Tonga and the Pacific. Here's what we know
  CNN · 14 minutes ago

View Full Coverage

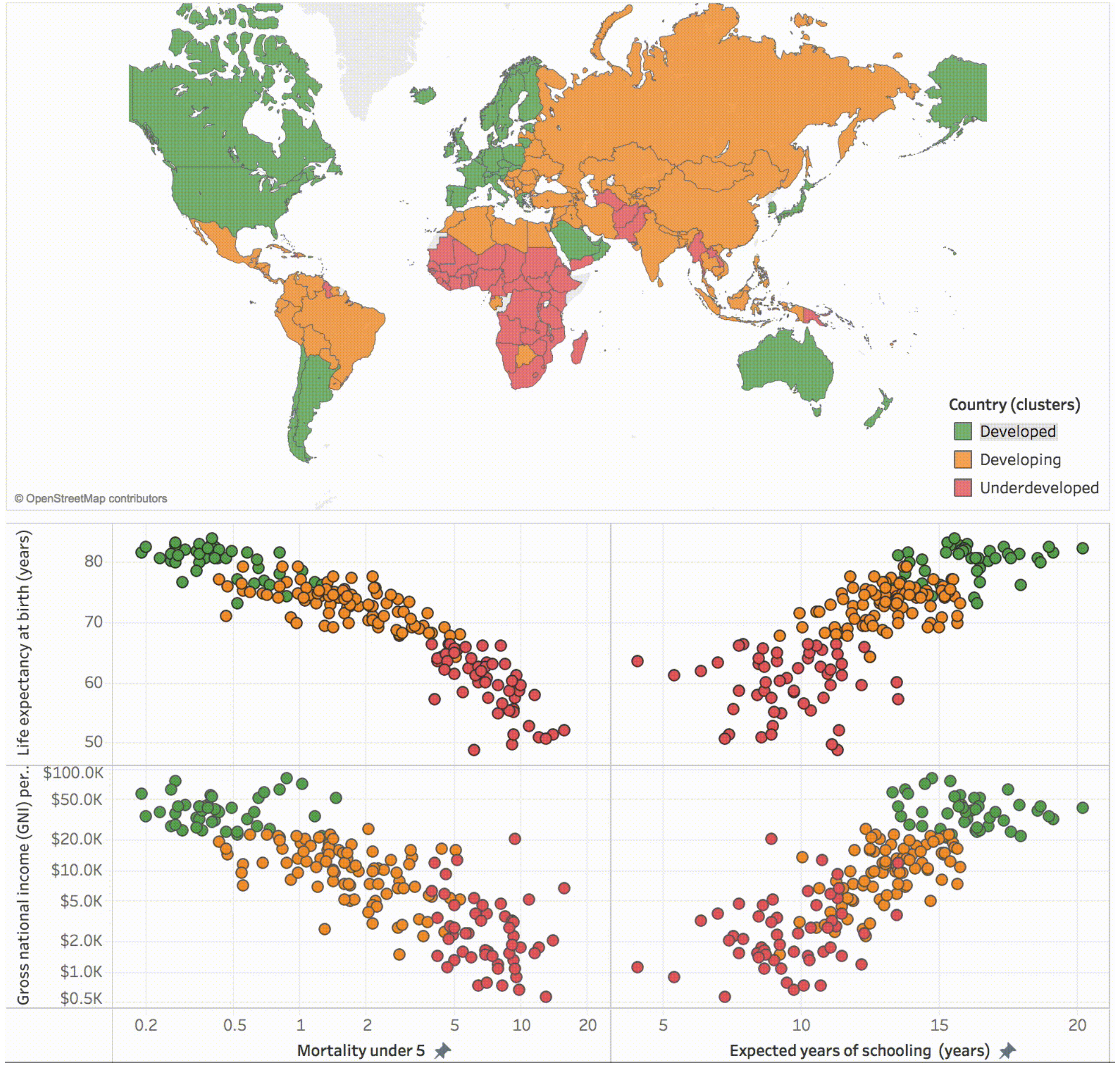
Tonga volcano Tsunami

Example : Clustering people

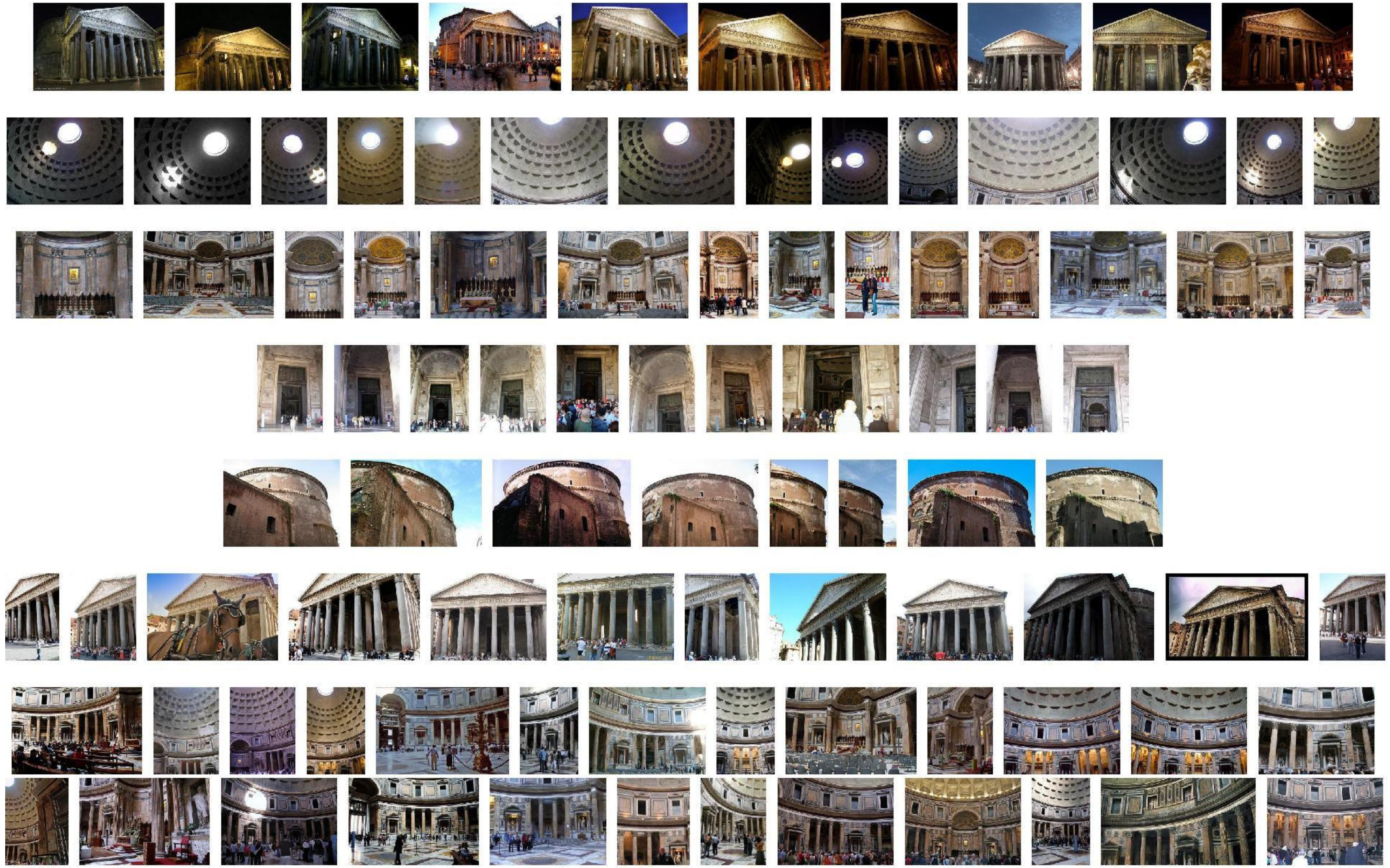
- **Six degrees of separation**
- **Small-world experiment**



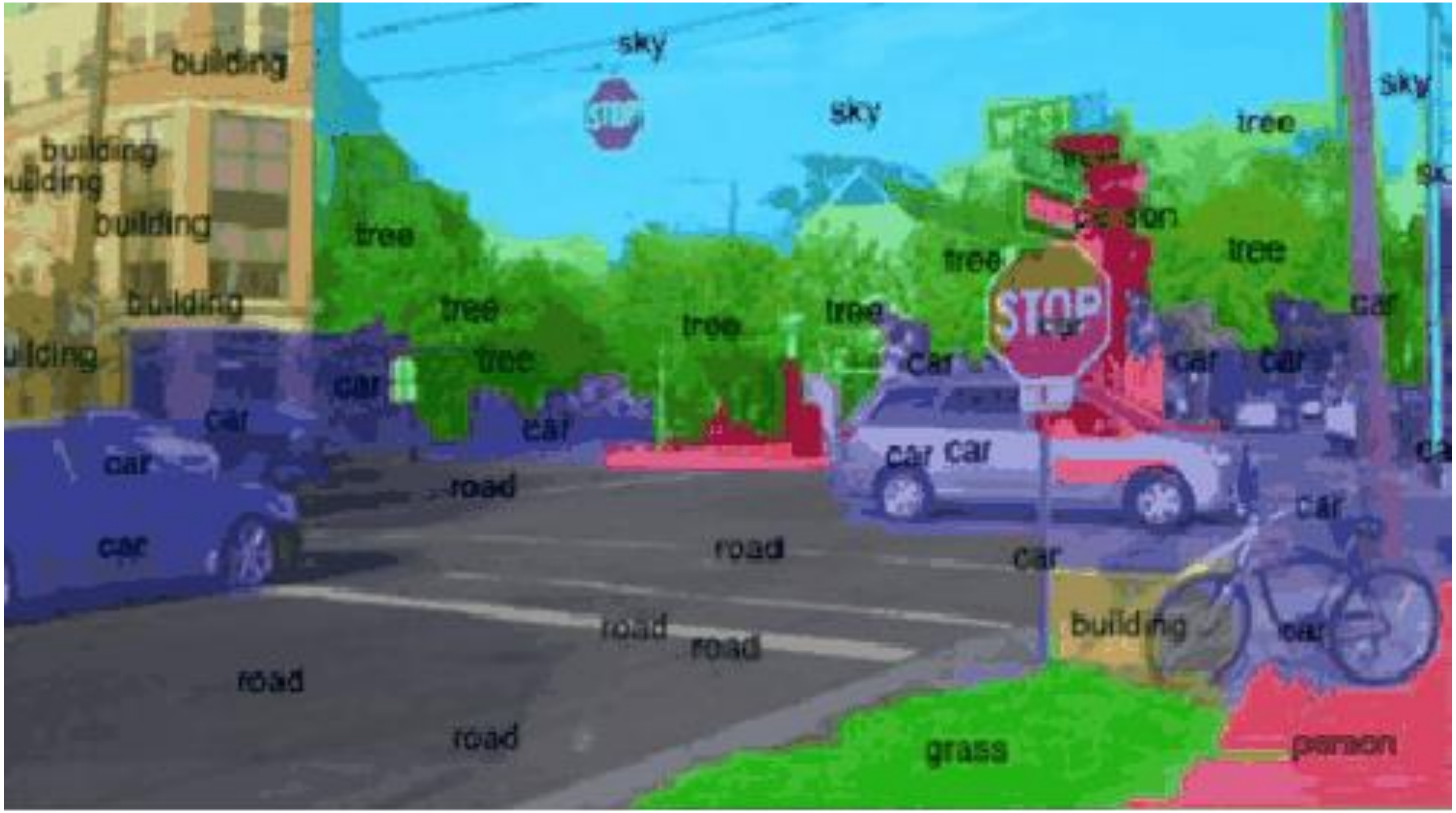
Example : Clustering countries



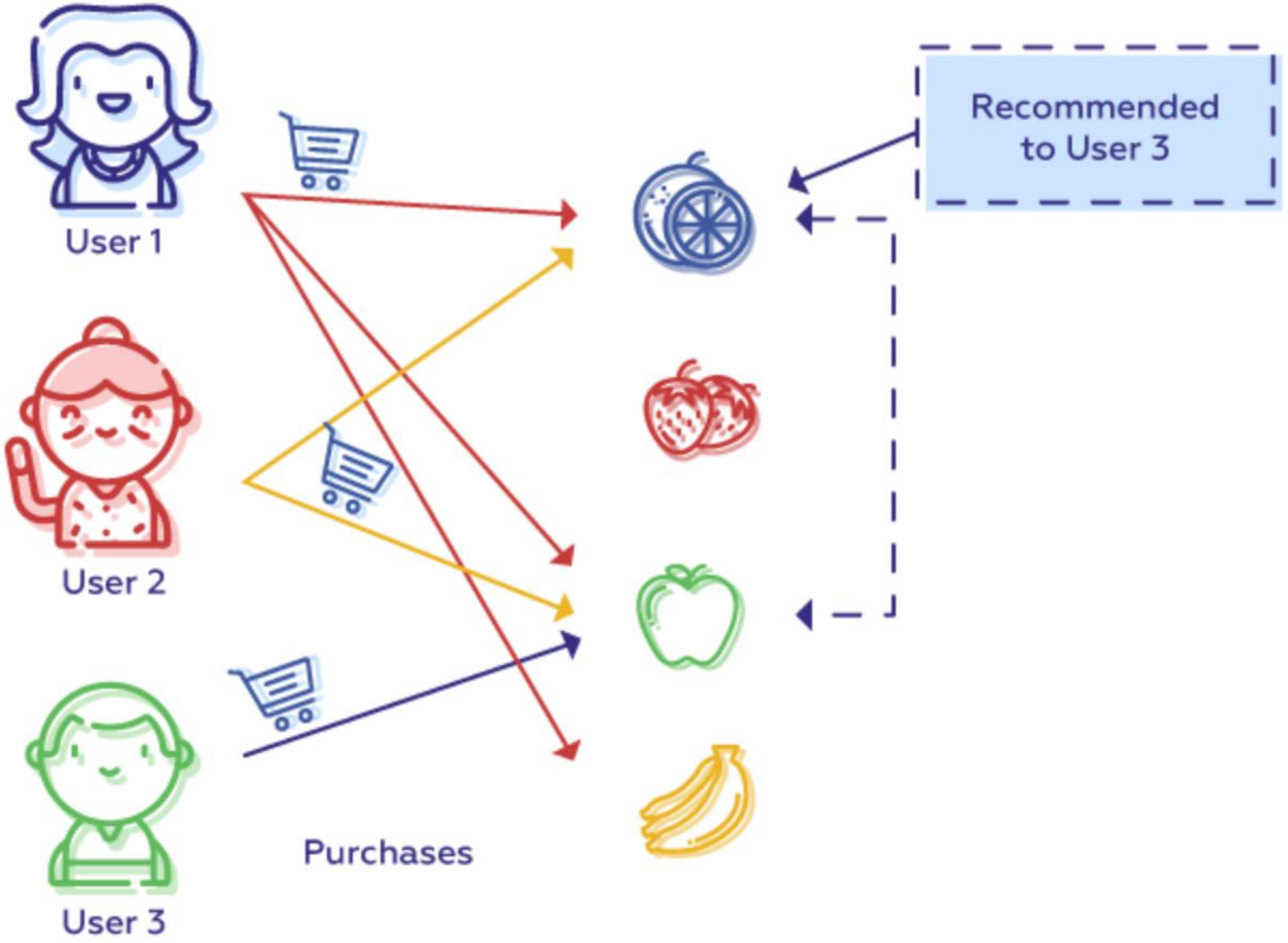
Example : Clustering images



Example : Clustering pixels



Example : Clustering items for recommendation

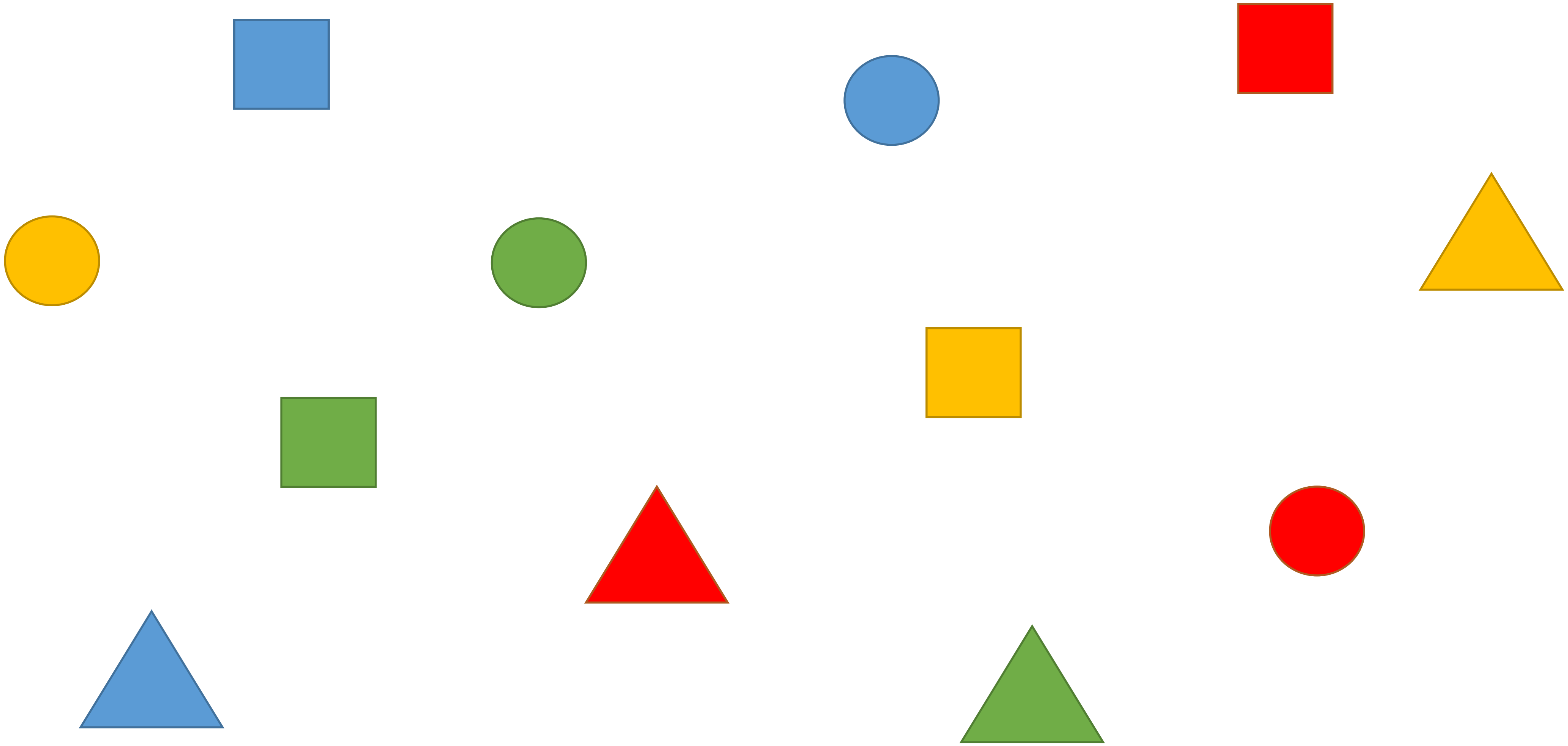


Examples

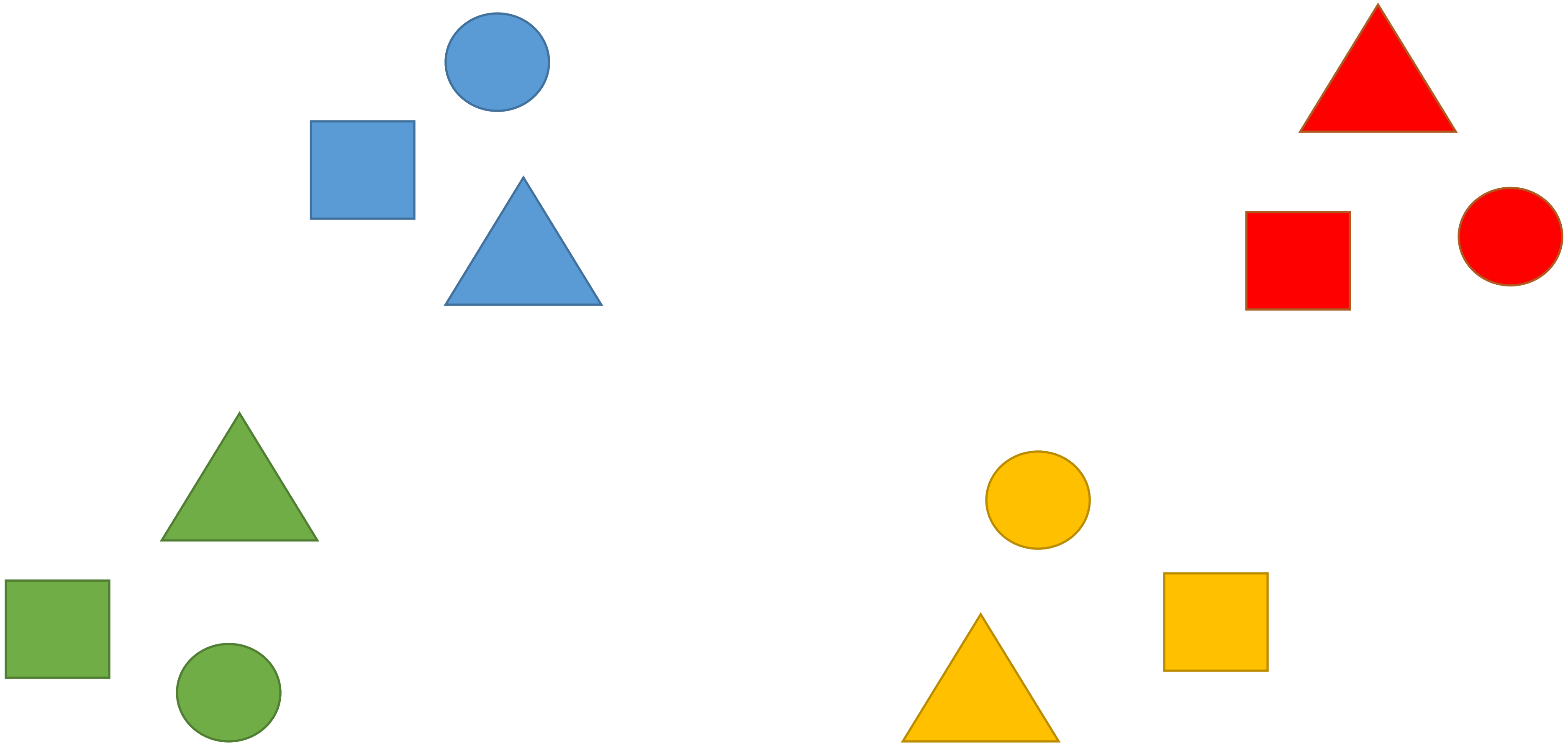
- What is the distance/similarity between :

- Two articles in news feeds ?
- Two images in a gallery ?
- Two pixels in a photo ?
- Two shows in a VOD service ?
- Two products in an e-commerce website ?
- Two persons in a social network ?
- Two ADN sequences ?

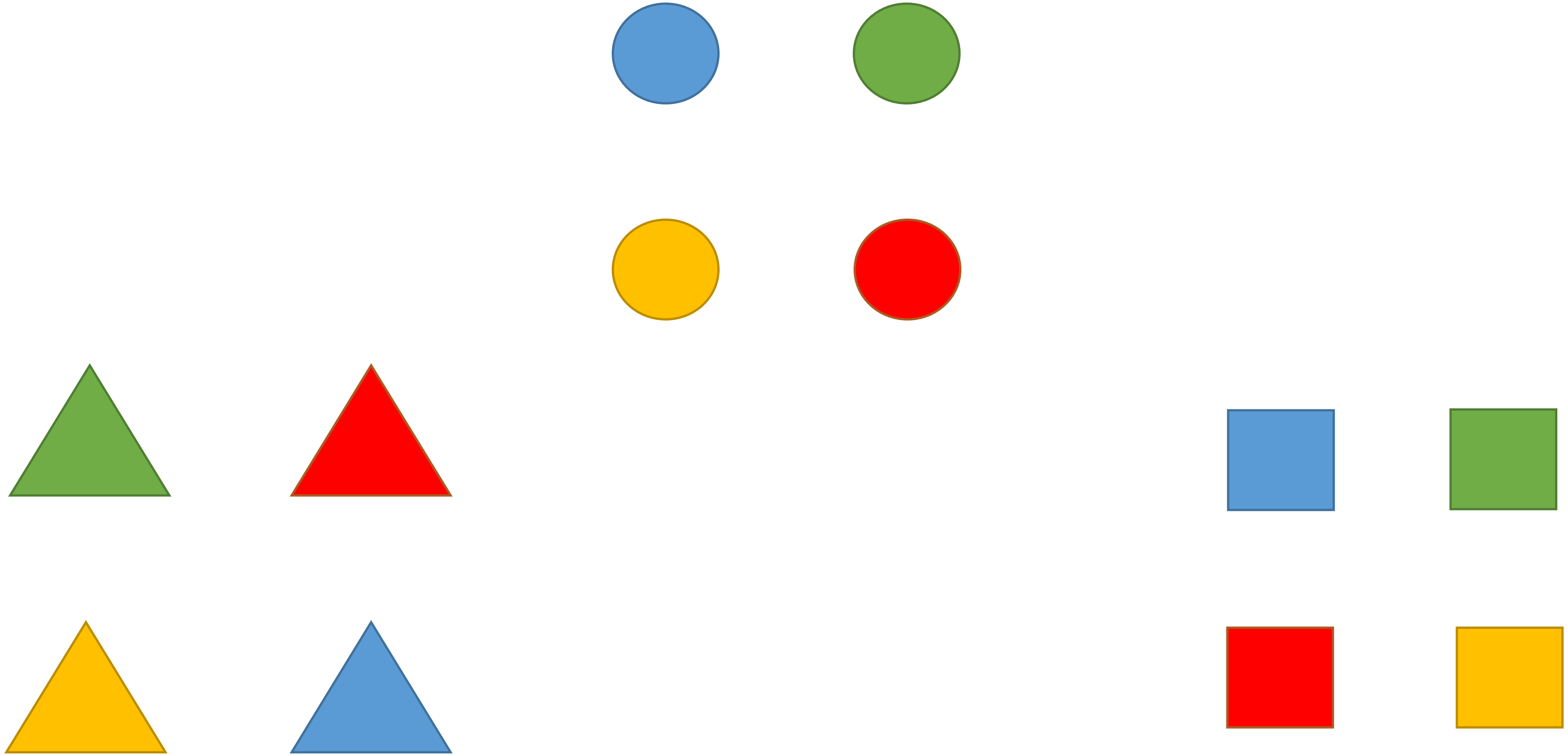
Grouping items with different colors and shapes



Based on color similarity → 4 groups



Based on shape similarity → 3 groups



The distance function

Distance axioms :

- The distance from a point to itself is null: d(x,x) = 0
- Positivity: d(x,y) >= 0
- Symmetry: d(x,y) = d(y,x)
- Triangle inequality: d(x,z) <= d(x,y) + d(y,z)

- Simplest case: one numeric attribute A

Distance(X,Y) = A(X) – A(Y)

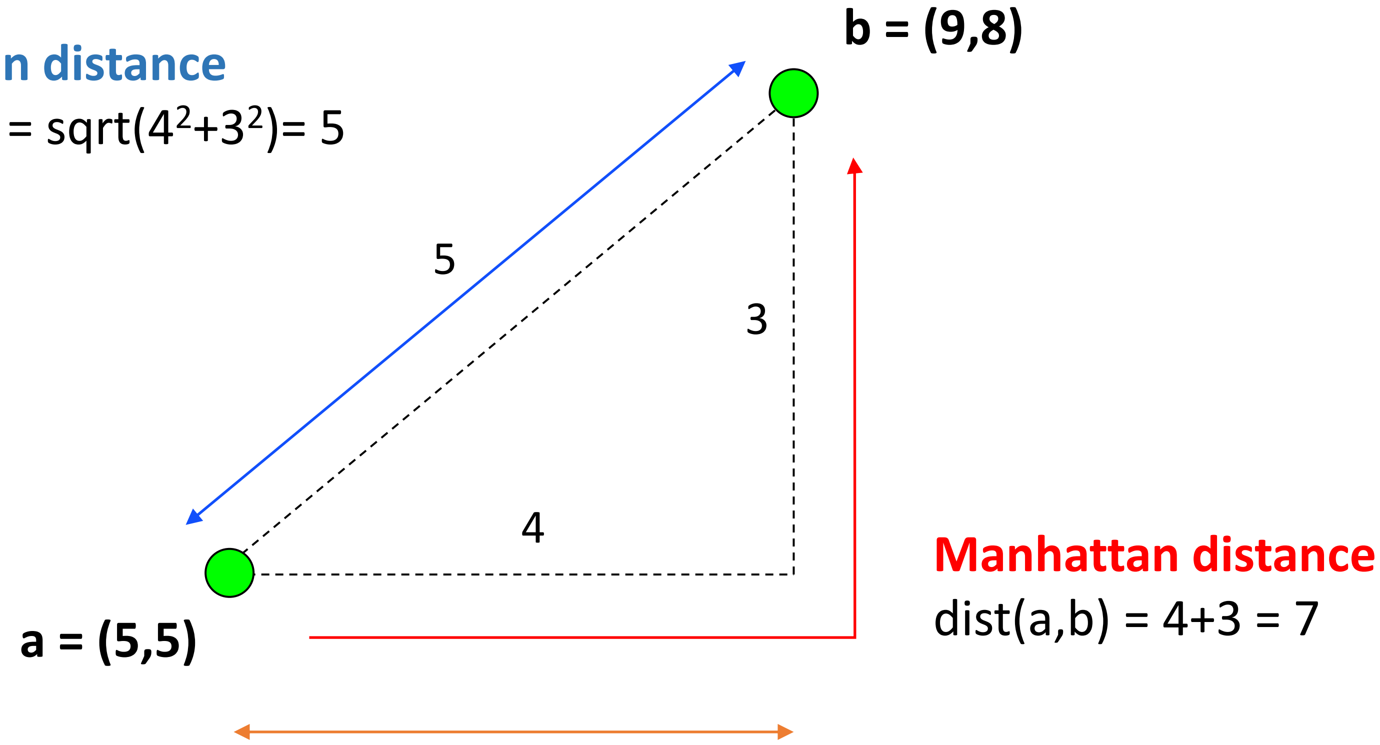
- Several numeric attributes:

Distance(X,Y) = Euclidean distance between X,Y

- Nominal attributes:

distance is set to 1 if values are different, 0 if they are equal

Examples of Euclidean Distances



Euclidean distance
dist(a,b) = sqrt(4^2+3^2)= 5

Manhattan distance
dist(a,b) = 4+3 = 7

Tchebychev distance
dist(a,b) = max(4,3) = 4

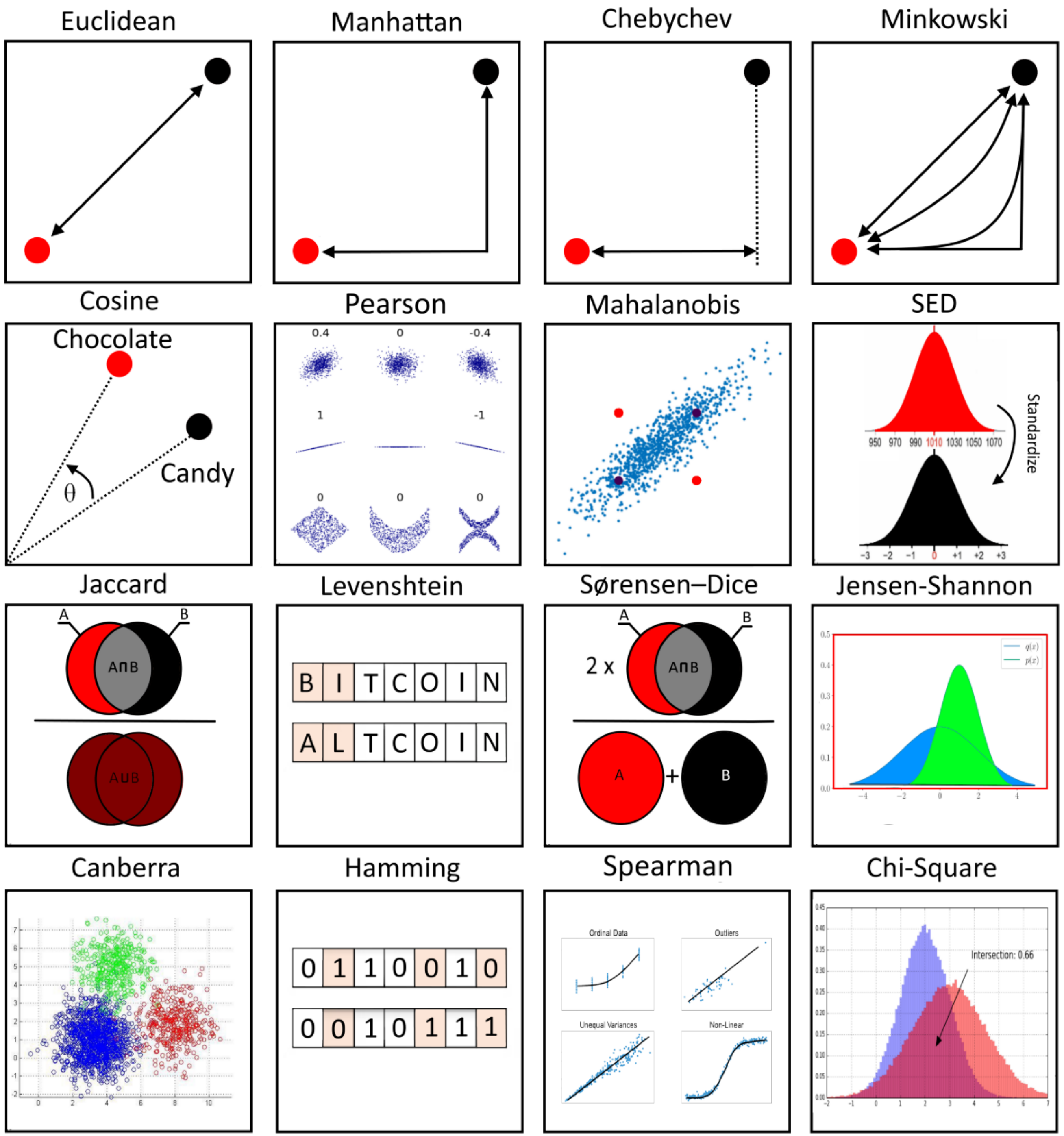
Distance / Similarity

How instances and samples
are related or close
to each other ?

Different ways to measure
depending on the nature of data
and the problems

https://docs.scipy.org/doc/scipy/reference/spatial.distance.html

You can also define your own
distance for your specific problem


Euclidean

Manhattan

Chebychev

Minkowski

Cosine

Pearson

Mahalanobis

SED

Jaccard

Levenshtein

Sørensen–Dice

Jensen-Shannon

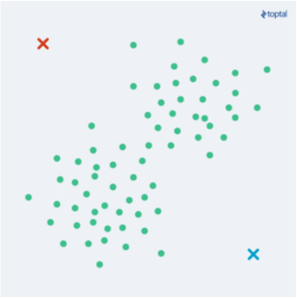
Canberra

Hamming

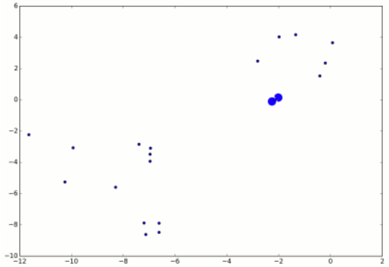
Spearman

Chi-Square

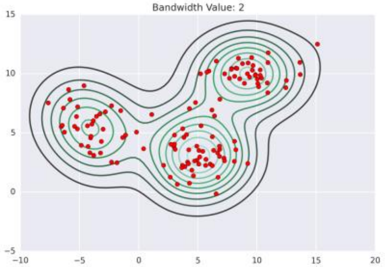
Some Clustering Algorithms



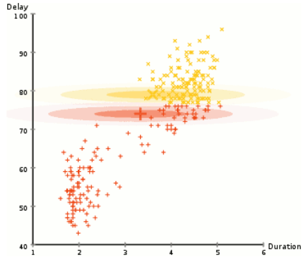
- K-means
  - Fix K. Iteratively re-assign points to the nearest cluster



- Agglomerative/Hierarchical clustering
  - Each point is a cluster. Iteratively merge the closest clusters



- Mean-shift clustering
  - Based on Kernel Density Estimation (KDE)



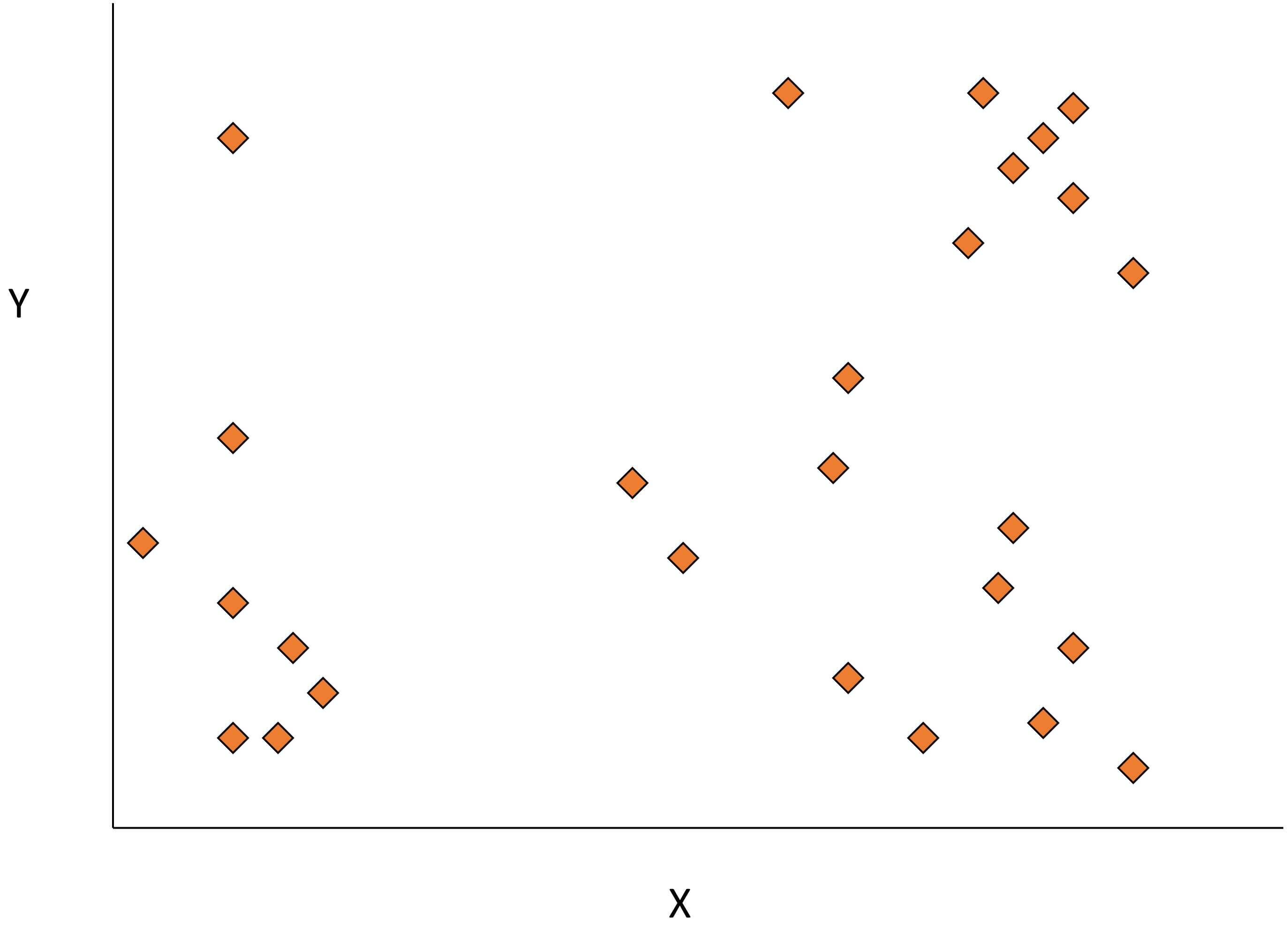
- EM Algorithm
  - Expectation of likelihood, Maximizing parameters
- And many others…

Simple Clustering: K-means

- Works with numeric data only
- Pick a number (K) of cluster centers (at random)
- Assign every item to its nearest cluster center (e.g. using Euclidean distance)
- Move each cluster center to the mean of its assigned items
- Repeat steps 2,3 until convergence (change in cluster assignments less than a threshold)

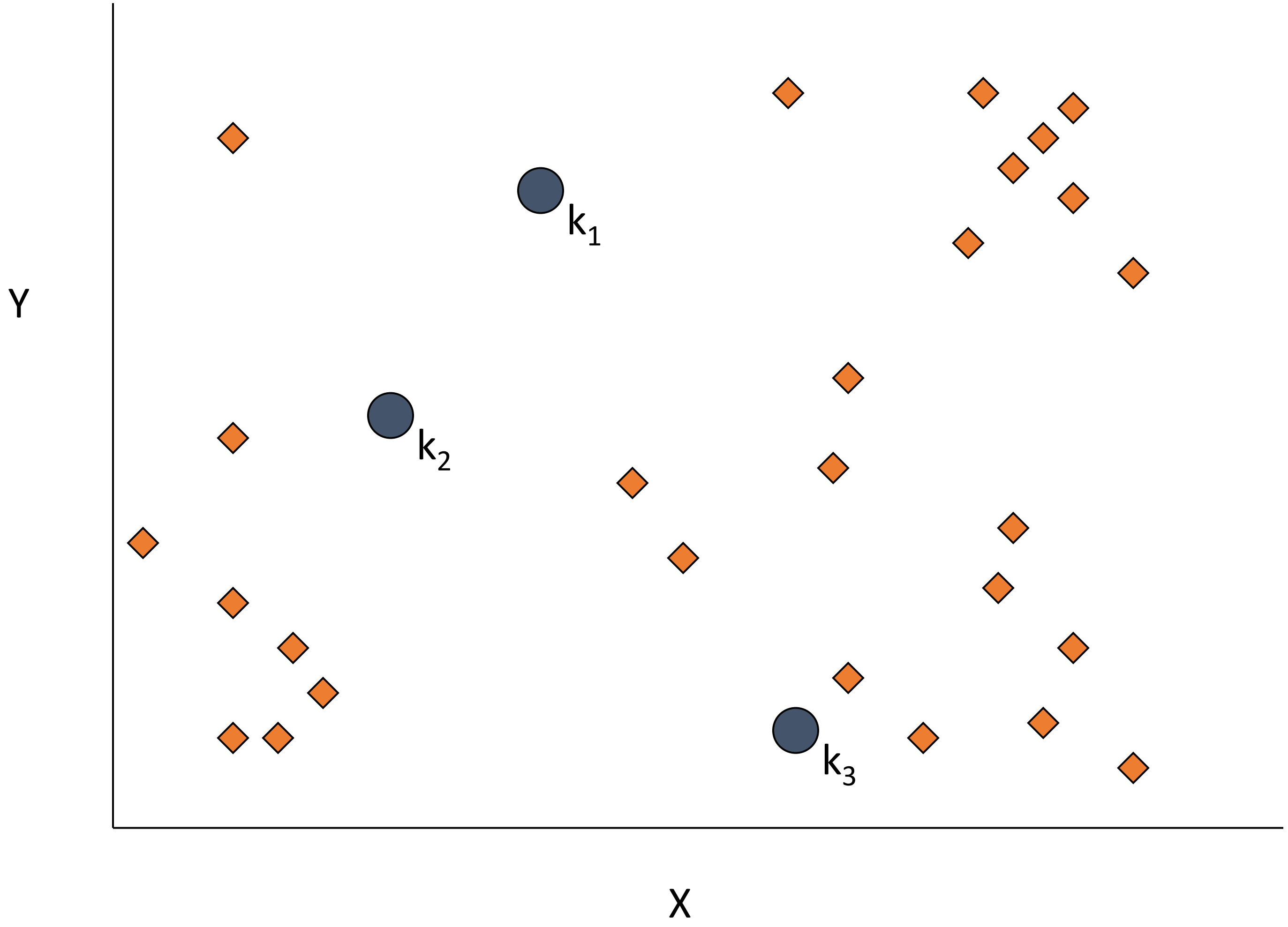
K-means example

Data
without labels



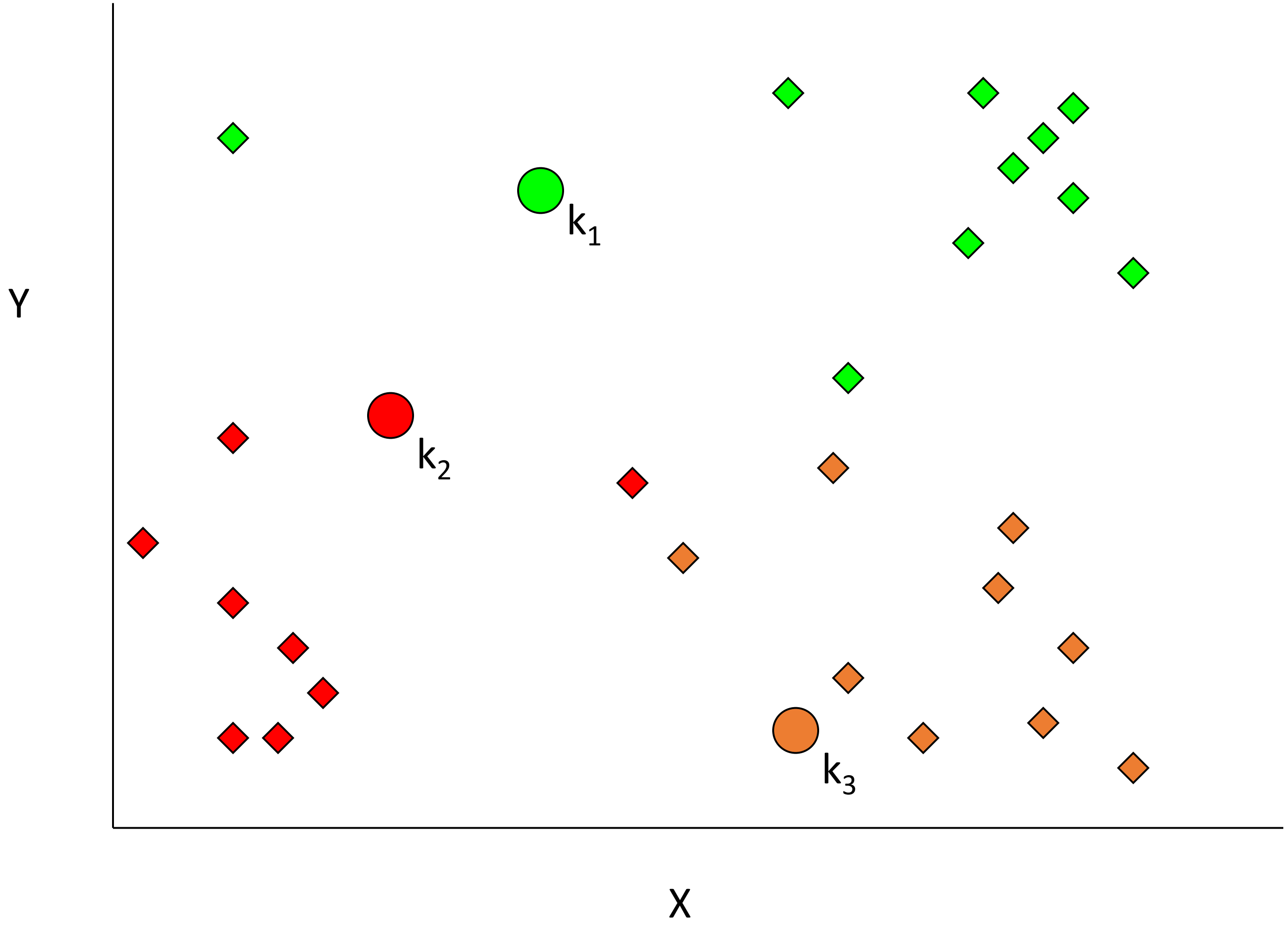
K-means example, step 1

Pick 3 initial cluster centers (randomly)



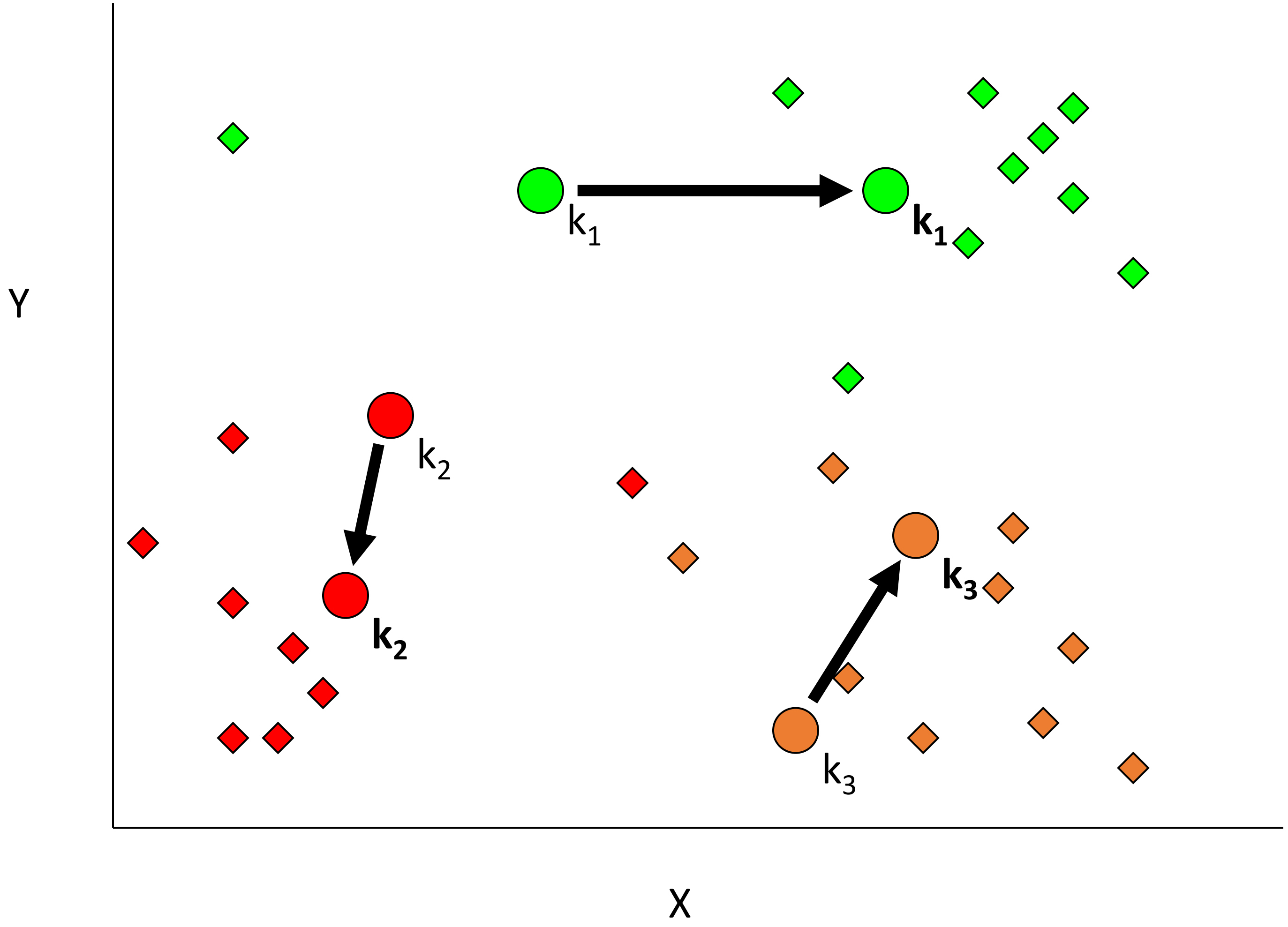
K-means example, step 2

Assign each point to the closest cluster center



K-means example, step 3

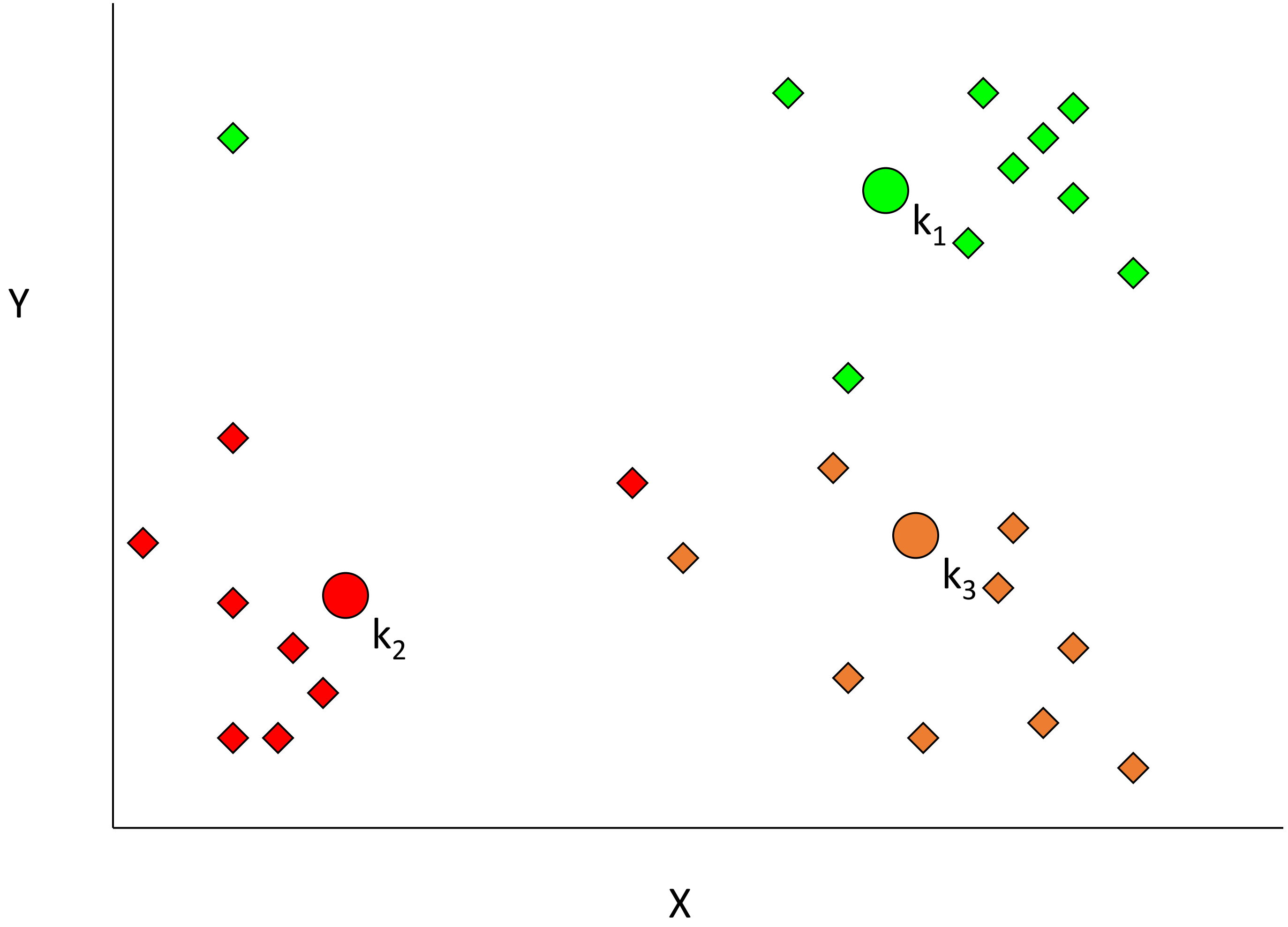
Move each cluster center to the mean of each cluster



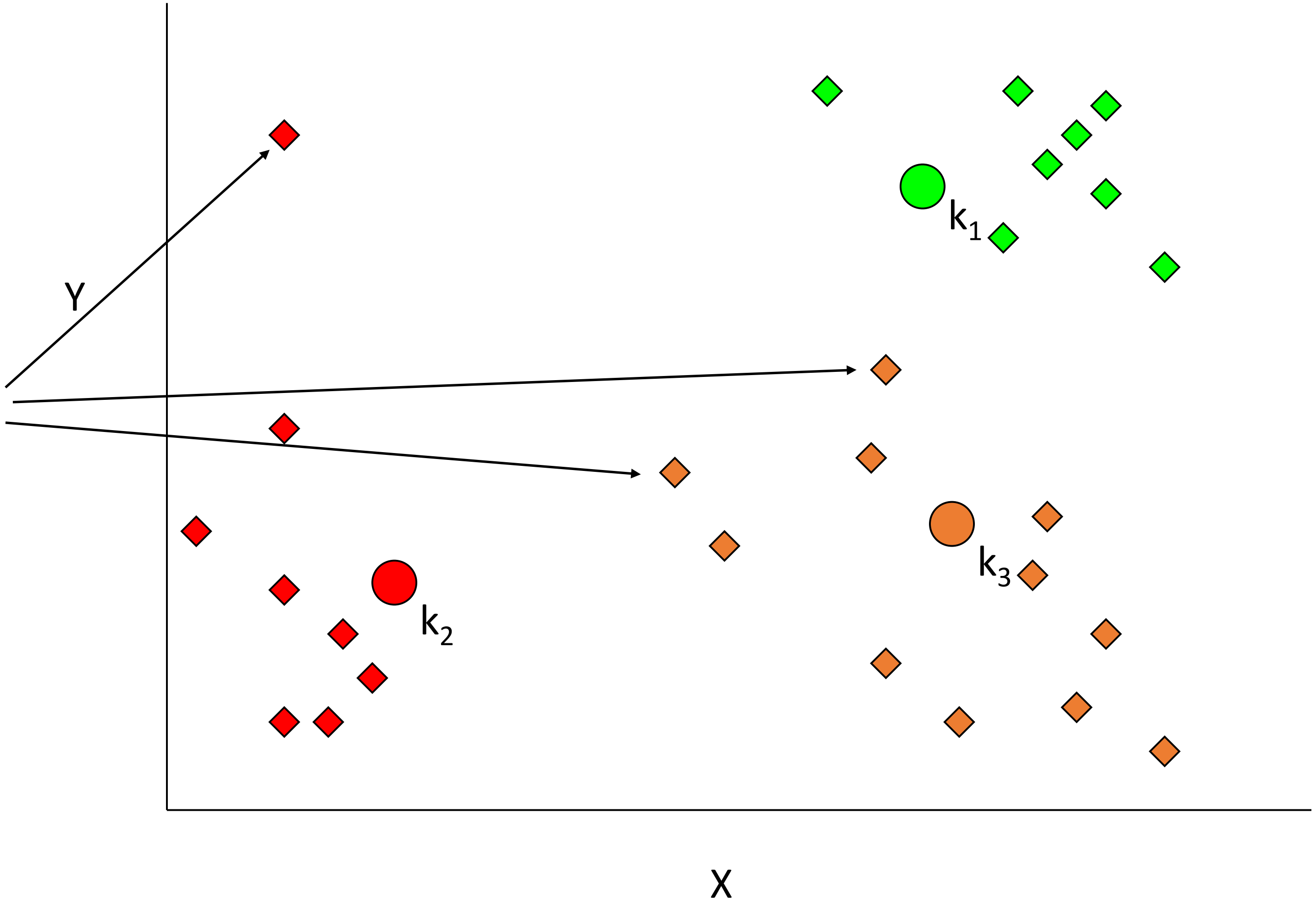
K-means example, step 4

Reassign points closest to a different new cluster center

Q: Which points are reassigned?



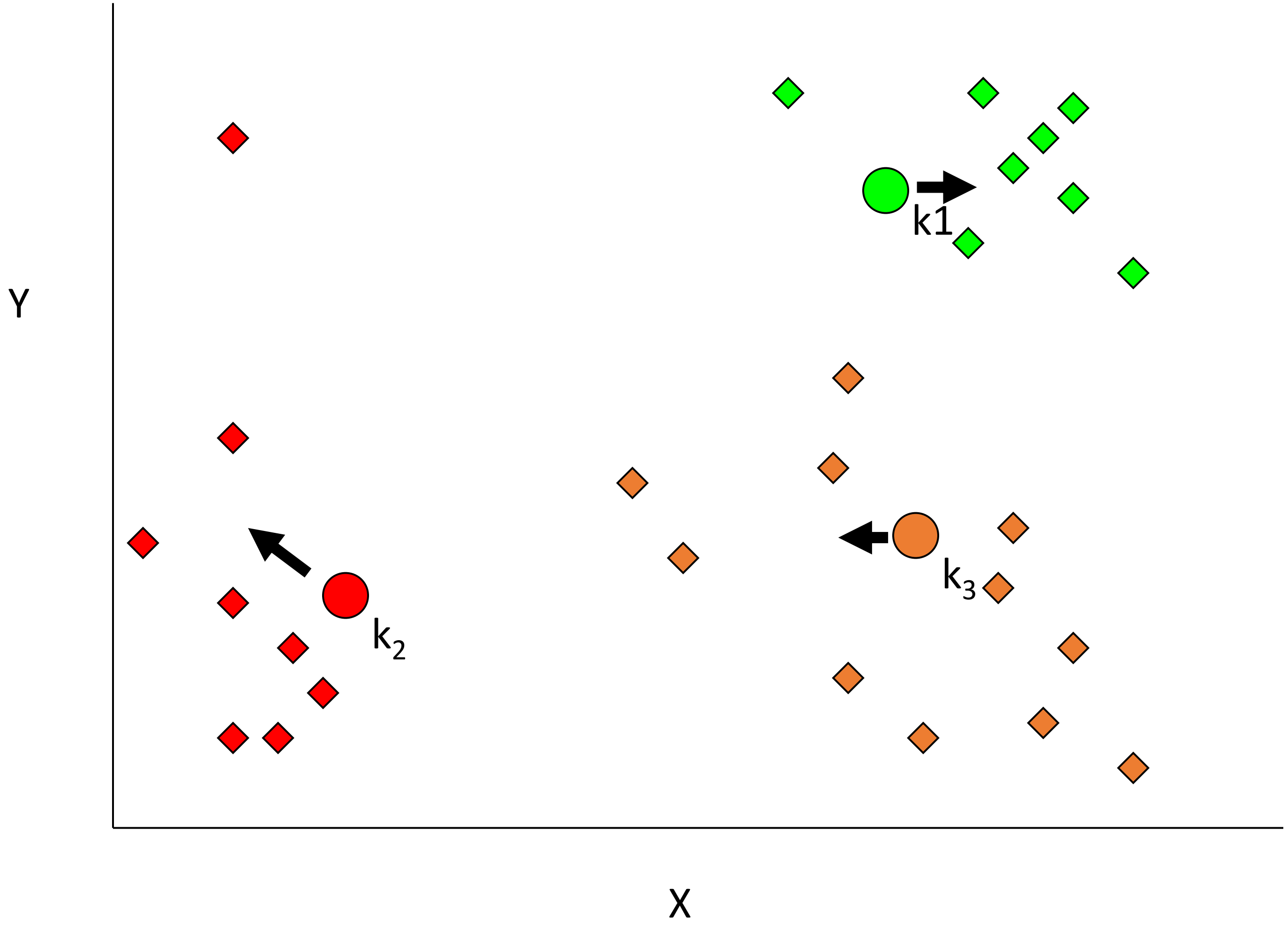
K-means example, step 4 …



for these three points ?

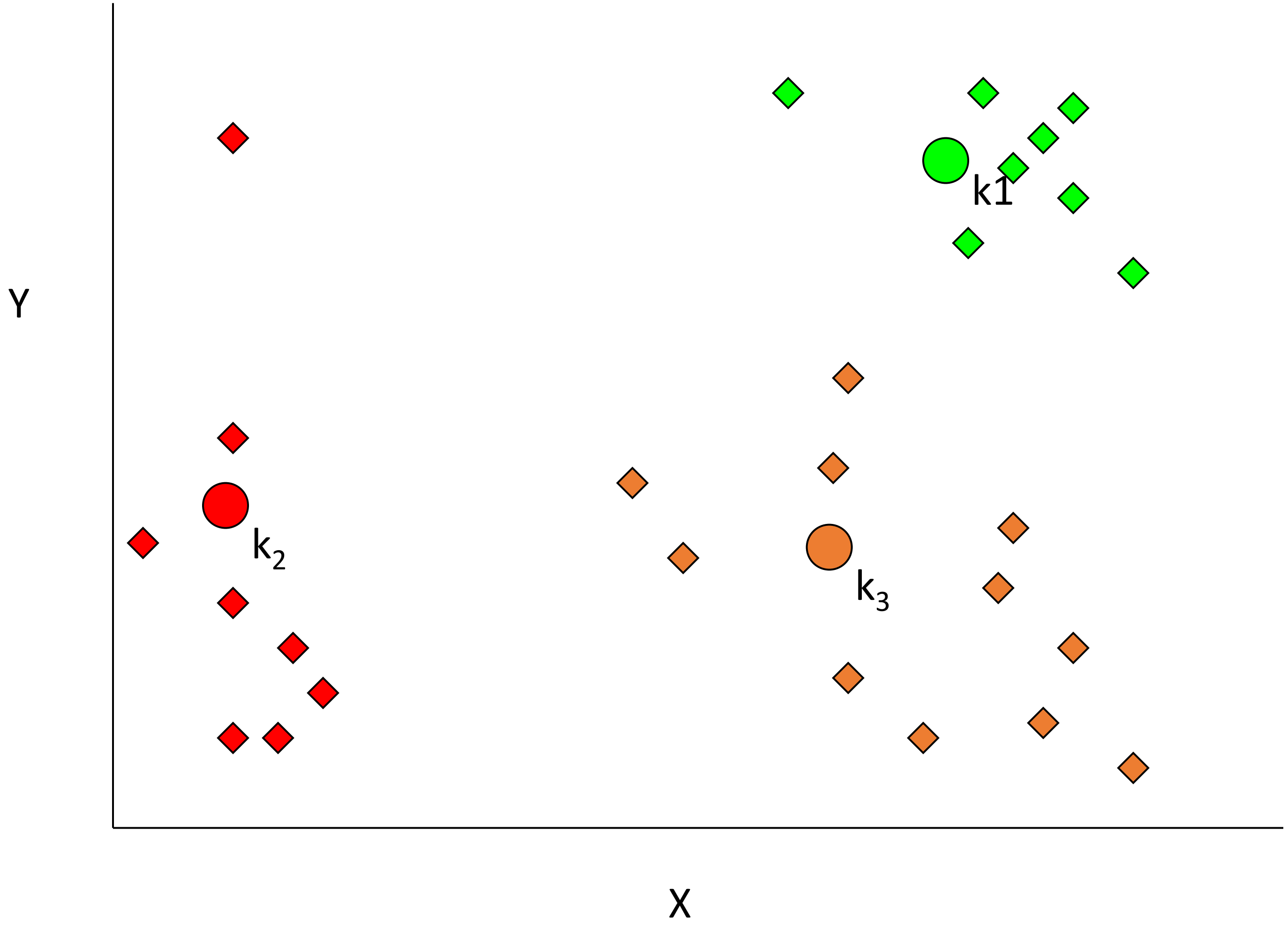
K-means example, step 4b

re-compute cluster means

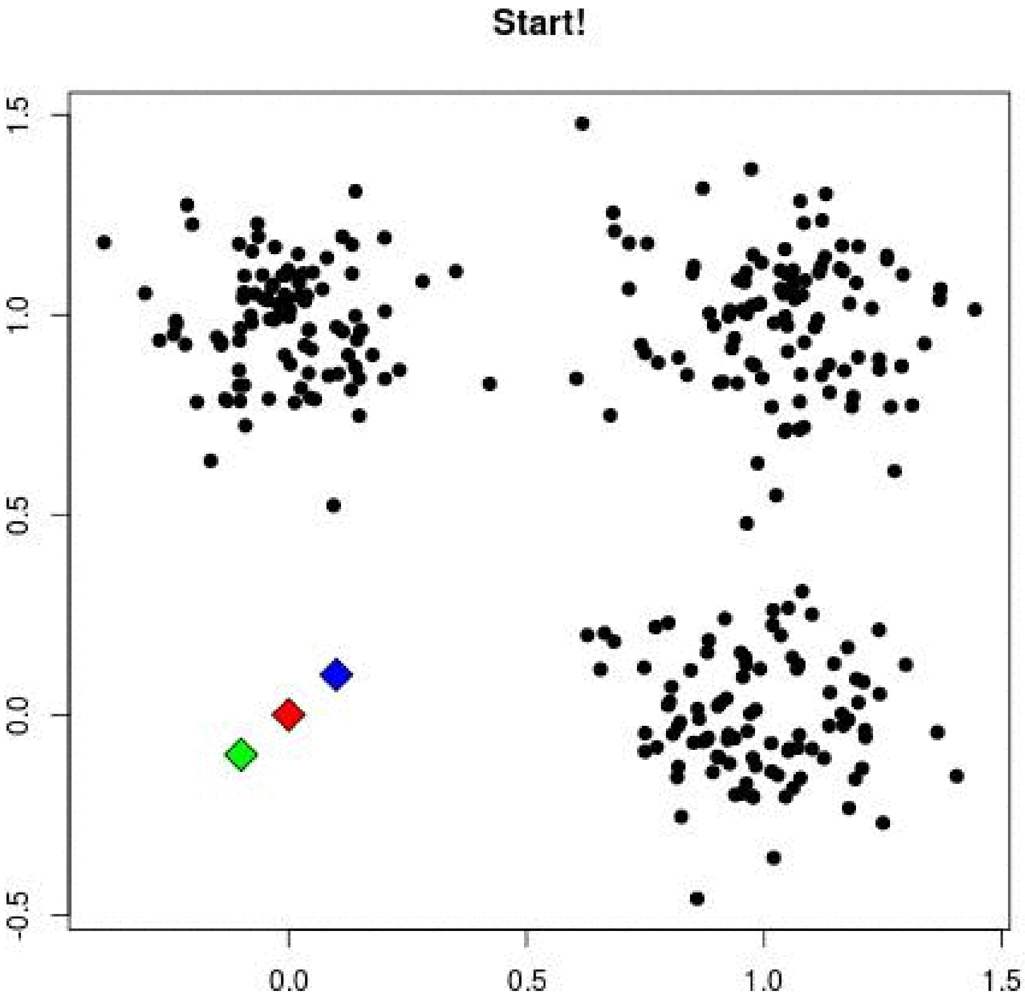


K-means example, step 5

move cluster centers to cluster means



K-means example, iterate…



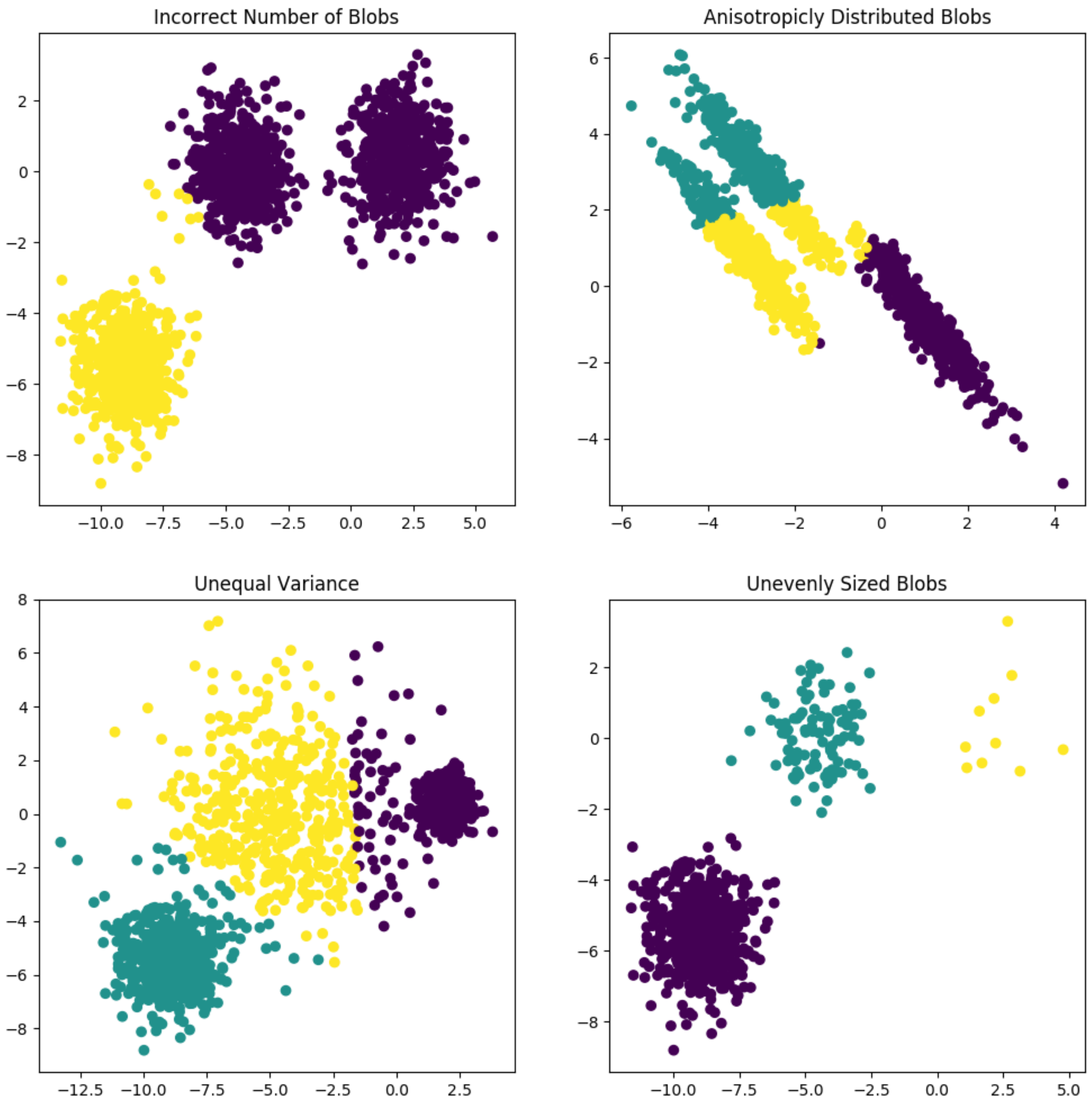
K-Means pros and cons

- **Pros**
  - Finds cluster centers that minimize conditional variance
  - Simple and fast
  - Easy to implement
  - …
- **Cons**
  - Need to choose K
  - Sensitive to outliers
  - All clusters have the same parameters
  - …

k-means assumptions

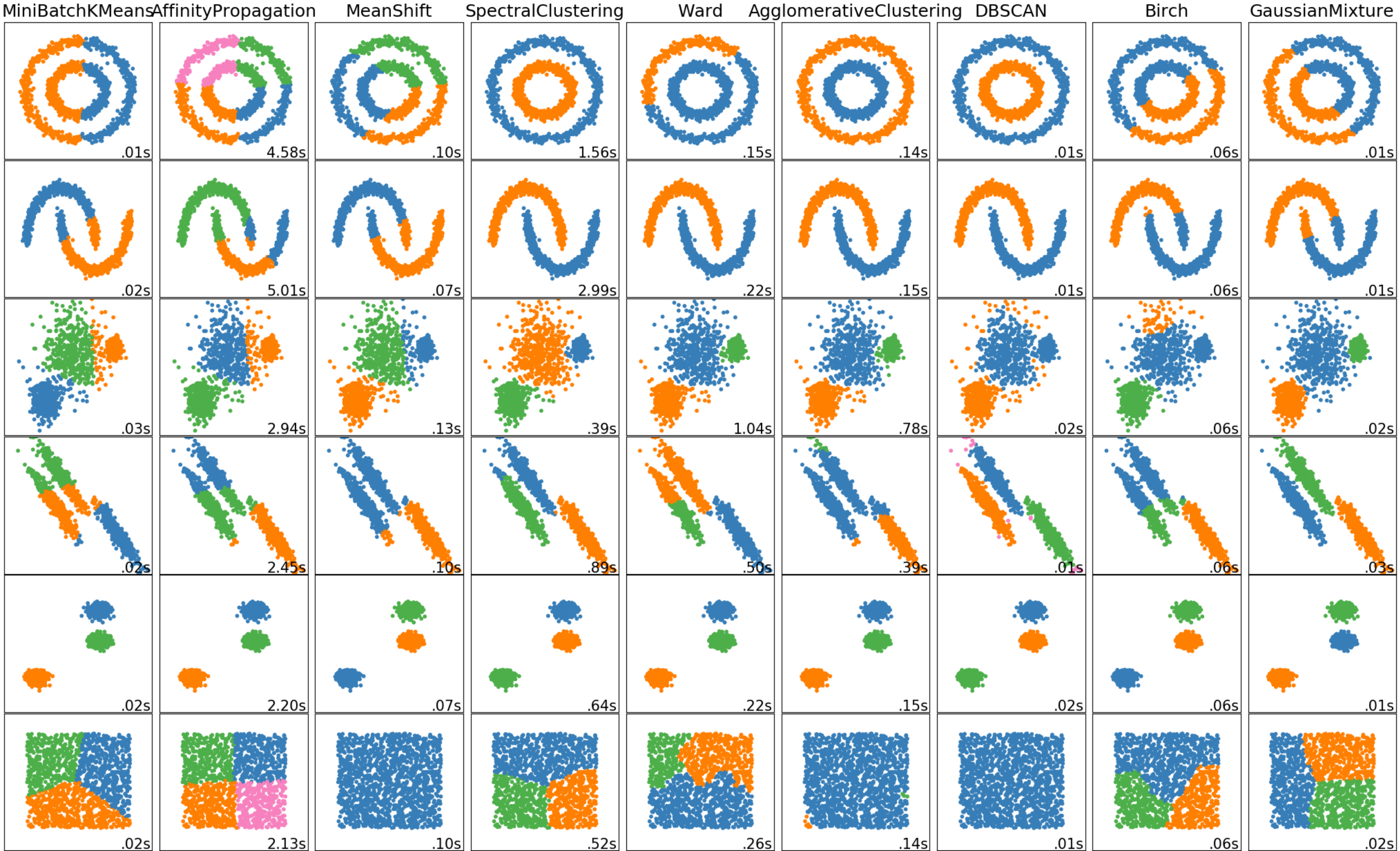
Situations where k-means will produce unintuitive and possibly unexpected clusters

Importance of dataviz



- Clustering in 2D looks easy
- Clustering small amounts of data look easy too

- Many applications involve more than 2D (Ex. > 10000 dimensions) with huge amounts of data


MiniBatchKMeans
AffinityPropagation
MeanShift
SpectralClustering
Ward
AgglomerativeClustering
DBSCAN
Birch
GaussianMixture
.01s
4.58s
.10s
1.56s
.15s
.14s
.01s
.06s
.01s
.02s
5.01s
.07s
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.22s
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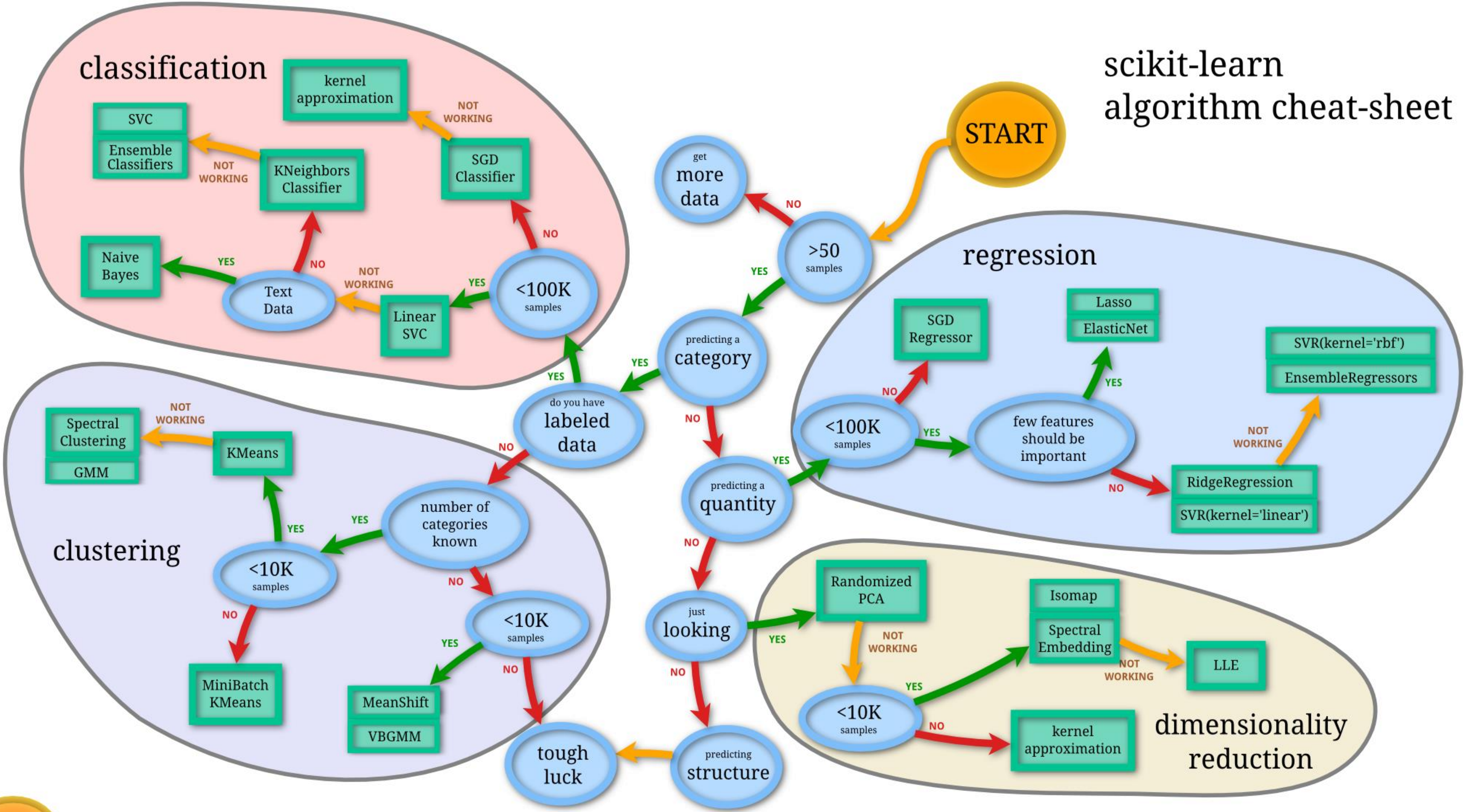
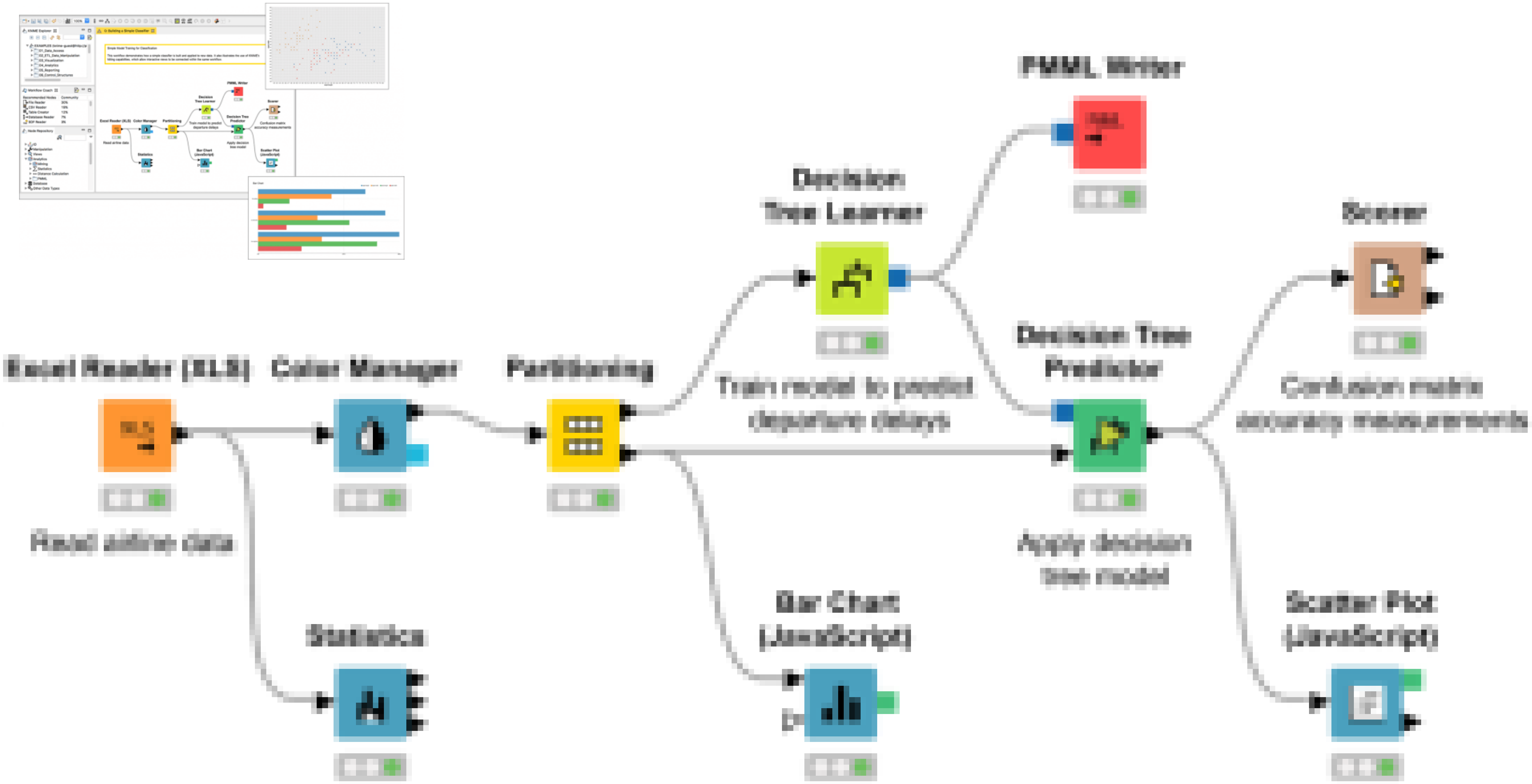
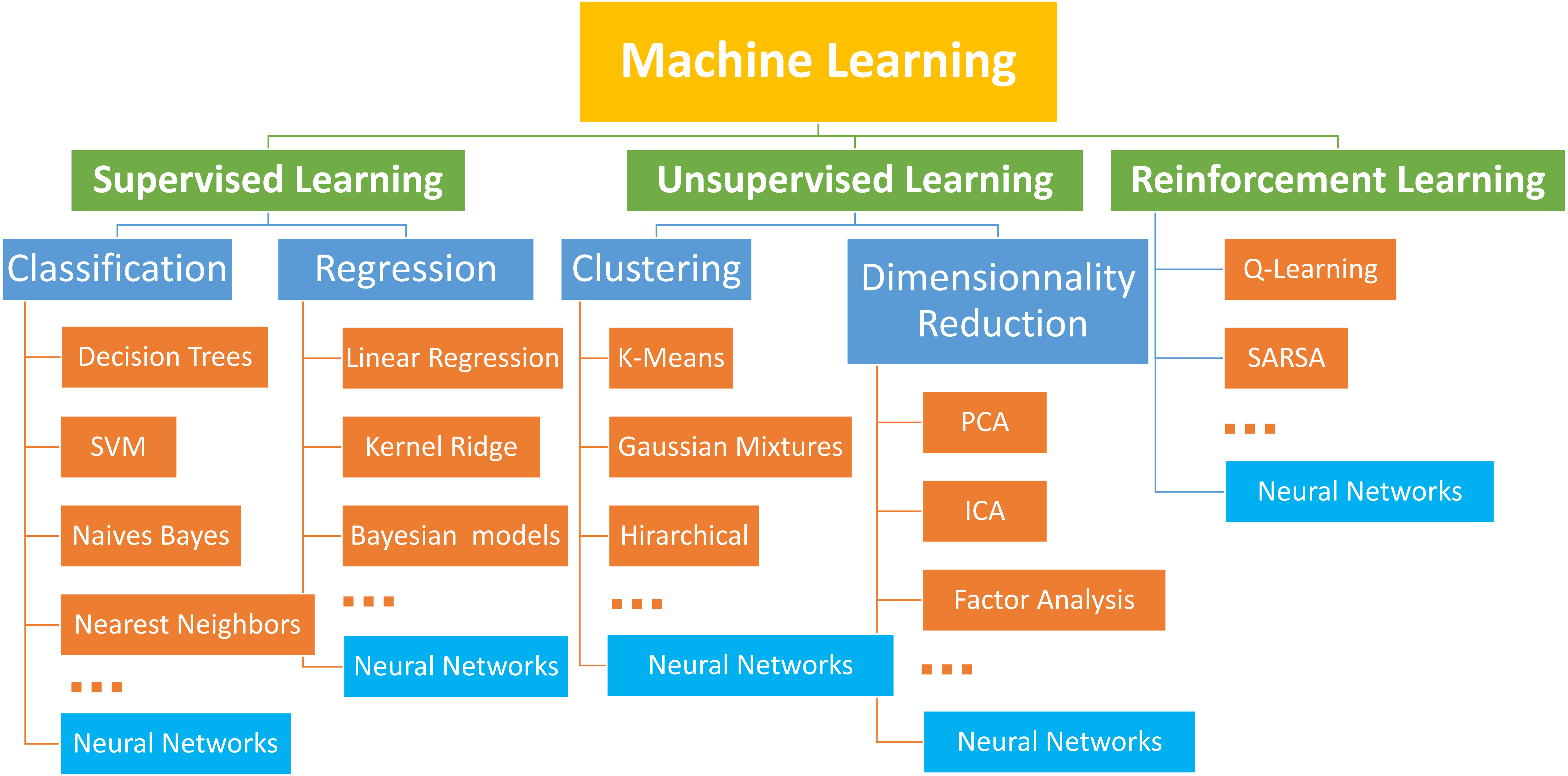
scikit-learn algorithm cheat-sheet



Back



https://www.knime.com/



- Machine Learning
  - Supervised Learning
    - Classification
      - Decision Trees
      - SVM
      - Naives Bayes
      - Nearest Neighbors
      - ...
      - Neural Networks
    - Regression
      - Linear Regression
      - Kernel Ridge
      - Bayesian models
      - ...
      - Neural Networks
  - Unsupervised Learning
    - Clustering
      - K-Means
      - Gaussian Mixtures
      - Hirarchical
      - ...
      - Neural Networks
    - Dimensionnality Reduction
      - PCA
      - ICA
      - Factor Analysis
      - ...
      - Neural Networks
  - Reinforcement Learning
    - Q-Learning
    - SARSA
    - ...
    - Neural Networks