7-Supervised Classification Models - K-Nearest Neighbors (KNN)

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What is KNN Algorithm?

https://youtu.be/0p0o5cmgLdE

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The k-nearest neighbor (k-NN) algorithm is a type of **non-parametric** method used for classification and regression.

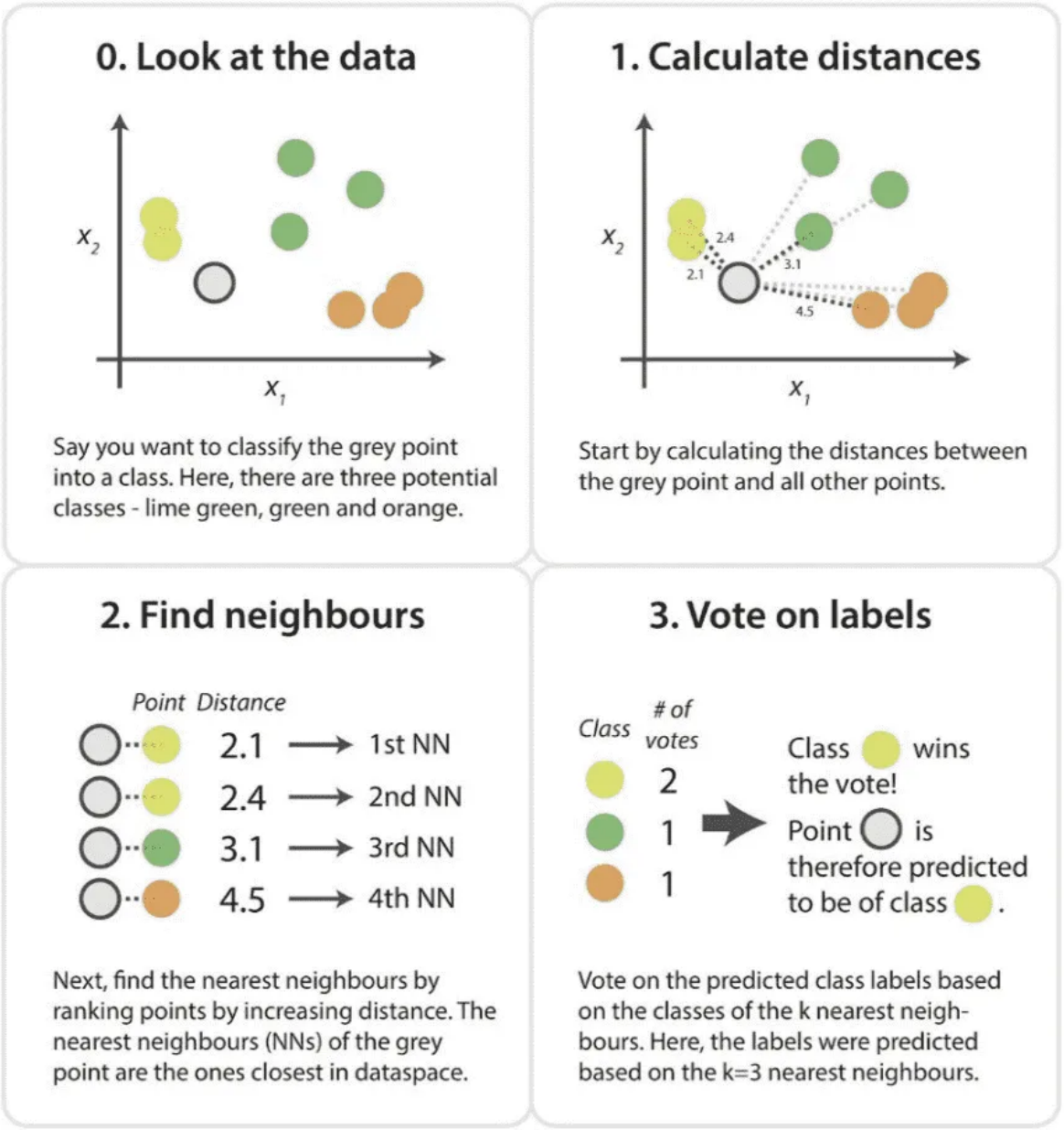
How KNN Works?

The k-NN algorithm is considered a **“lazy learning”** algorithm because it doesn’t build a model until a new instance is given for classification or regression. This also means that the algorithm **doesn’t require any training data in advance.**

In Short: The basic idea behind the algorithm is to **find the k number of closest instances in the training dataset for a new instance and have them “vote”** on the class or value of the new instance. The class or value with the most votes is then assigned to the new instance.

In Steps:

1. Initialize the value of k
2. For getting the predicted class, iterate from 1 to total number of training data points
    - Calculate the distance between test data and each row of training dataset.
    - Sort the calculated distances in ascending order based on distance values
    - Get top k rows from the sorted array
    - Get the most frequent class of these rows
    - Return the predicted class

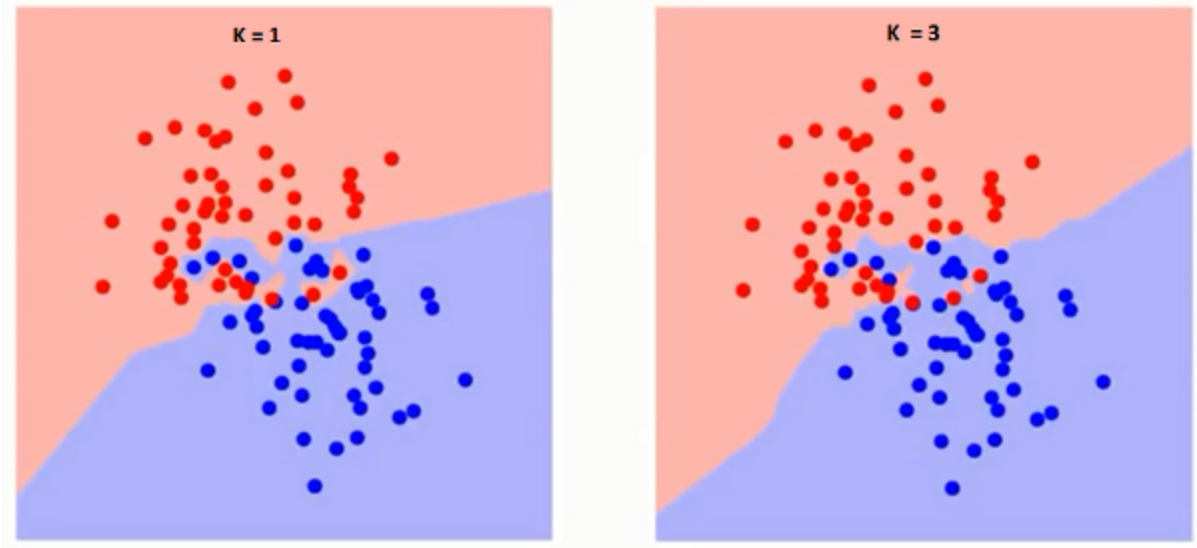


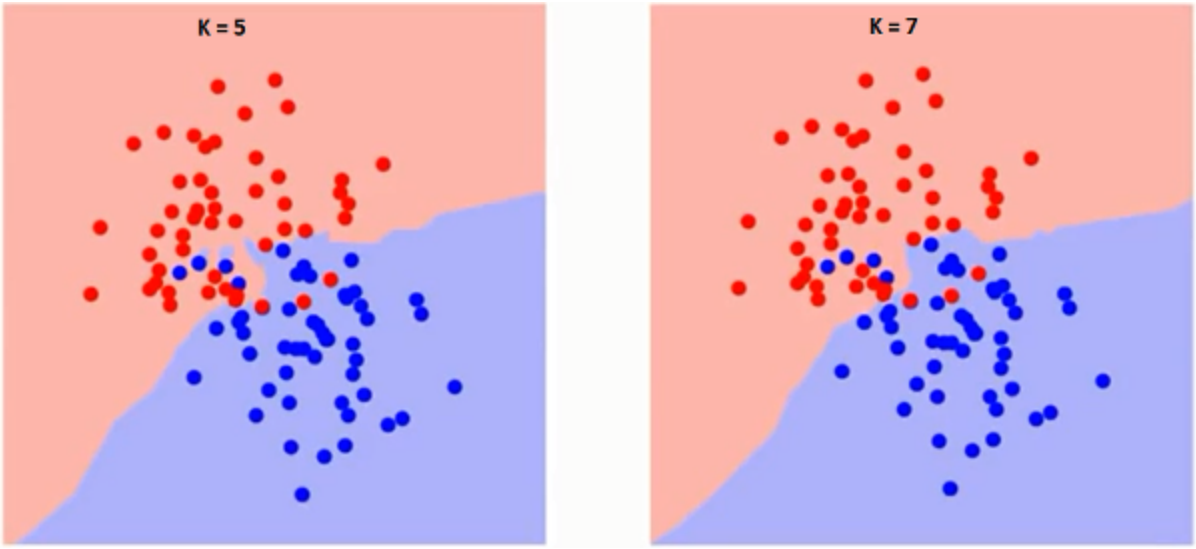
Demo:

- https://adotg.github.io/knn-what-how-why/
- https://www.philippe-fournier-viger.com/tools/KNN.php
- https://codepen.io/gangtao/pen/PPoqMW

How to fine best K?

- In k-NN classification, the value of k is **typically small,** such as k=1 or k=3. A k-value of 1 means that the new instance is assigned to the class of its nearest neighbor. A larger k-value, such as k=3, means that the new instance is assigned to the class that is most common among its 3 nearest neighbors.
- In k-NN regression, the value of k is typically set to an odd number to avoid tiebreakers.
- If you watch bellow carefully, you can see that the boundary becomes smoother with increasing value of K. With K increasing to infinity it finally becomes all blue or all red depending on the total majority.





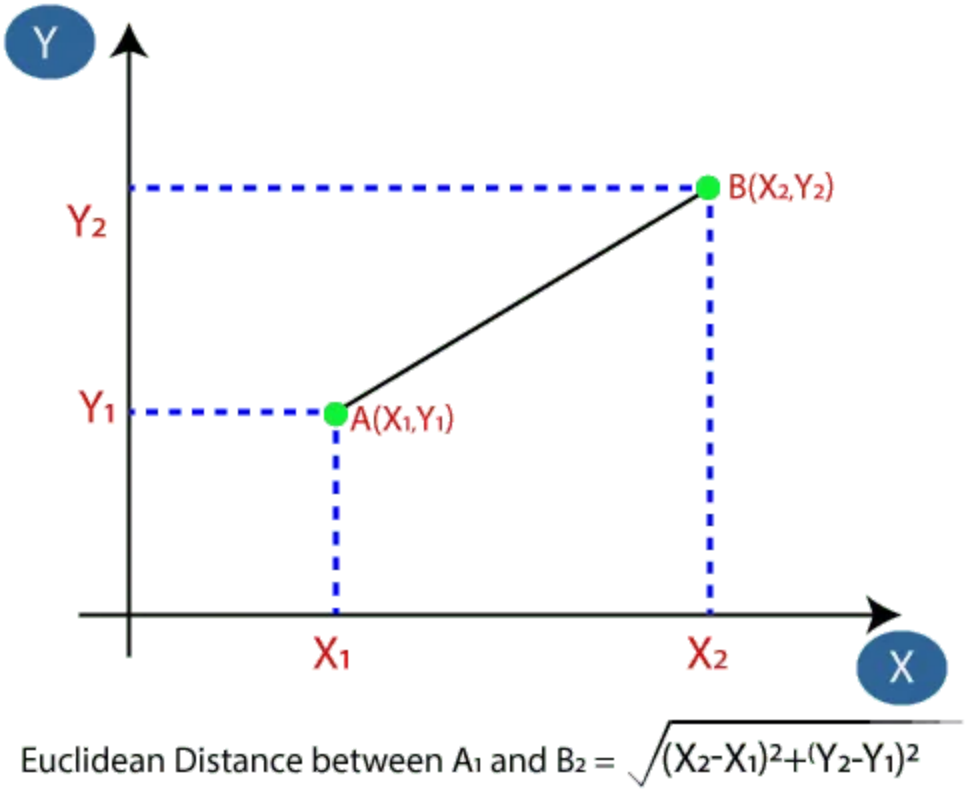
- One can use cross-validation to select the optimal value of k for the k-NN algorithm, which helps improve its performance and prevent overfitting or underfitting.

How to calculate distance?

k-NN algorithm uses the **distance metric** to measure the similarity between a new instance and the instances in the training dataset

Distance metric type:

1. **Euclidean Distance:** Euclidean distance is calculated as the square root of the sum of the squared differences between a new point (x) and an existing point (y).



Euclidean Distance between A_1 and B_2 = $\sqrt{(X_2-X_1)^2+(Y_2-Y_1)^2}$

2. **Manhattan Distance:** This is the distance between real vectors using the sum of their absolute difference.

Distance functions

Euclidean $\sqrt{\sum_{i=1}^{k}(x_i - y_i)^2}$

Manhattan $\sum_{i=1}^{k}|x_i - y_i|$

3. **Hamming Distance:** It is used for categorical variables. If the value (x) and the value (y) are the same, the distance D will be equal to 0 . Otherwise D=1.

$$D_H = \sum_{i=1}^{k} |x_i - y_i|$$

$$x = y \Rightarrow D = 0$$

$$x \neq y \Rightarrow D = 1$$

Preprocessing steps for features:

1. Create dummy variables out of a categorical variable and include them instead of original categorical variable
2. Standardize variables before calculating distance.

Example Calculation:

Assume:

- We have a data set with 4 features:
  - First point:
    - P = (1, 2, "red", "small")
  - Second point:
    - Q = (5, 6, "red", "small"))
- Distance for continuous features:
  - $d_c = \sqrt{(1-5)^2 + (2-6)^2} = \sqrt{16+16} = \sqrt{32}$
- Distance for categorical features:
  - $d_k = 2$ (since both features differ)
- Combined Distance:
  - $d = \sqrt{32+4} = \sqrt{36}$

Pros

1. Easy to understand
2. No assumptions about data
3. Can be applied to both classification and regression
4. Works easily on multi-class problems

Cons

1. Memory Intensive / Computationally expensive
2. Sensitive to scale of data
3. Low k-value is sensitive to outliers and a higher K-value is more resilient to outliers as it considers more voters to decide prediction.
4. Struggle when high number of independent variables
5. Choosing the right value of **K** can be tricky.

Resources:

- https://www.freecodecamp.org/news/k-nearest-neighbors-algorithm-classifiers-and-model-example/