Statistical Learning and Neural Networks
A.A. 2020/2021

Computer Lab 1 – k-NN classifier
Duration: 6 hours

Exercise 1 – Synthetic dataset

In this exercise, you will employ a synthetic dataset (file `synthetic.mat`), containing labelled training data and test data for two classes. Each example is 2-dimensional.

Task: your task is to implement a k-NN classifier in Matlab, which calculates the probability that a given test example belongs to each class, and outputs a class label as the class with the highest probability. You will evaluate the classifier performance computing the average classification accuracy (i.e. the fraction of test examples that have been classified correctly).

In particular, you should perform the following:

- Train a k-NN classifier for different values of k.
- Compare accuracy on the training set and the test set. Calculating accuracy of the training set means that you will have to classify each sample in the training set as if it were a test sample; one expects that classification of training samples will perform well, and this may also be used to validate your implementation.
    - Accuracy is defined as the ratio between the number of test samples that are correctly classified, and the total number of test samples.
- Identifying overfitting and underfitting in the obtained results.

Note that, for this computer lab, you do not need to employ a validation set.

Other indications:

- It is not allowed to employ Matlab's `knnsearch( )` function (this also holds for exercise 2). Only basic functions can be employed. It is allowed to employ the `mink( )` function. This is only available from Matlab R2017b; else the `sort( )` function can be used.

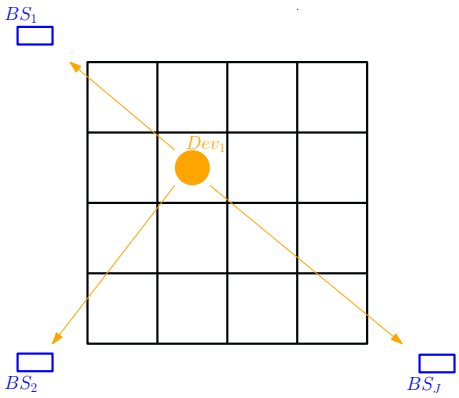
Exercise 2 – Phoneme recognition

In this exercise, a real dataset will be employed. The dataset (`speech_dataset`) contains 5 features for each window of speech signal, with the aim to distinguish between nasal (class 1) and oral sounds (class 2). The five features are the normalized amplitudes of the five first harmonics of the speech signal. More information can be found here: https://www.openml.org/d/1489

The data set contains features for 5404 speech samples (the 6-th column is the class label). The dataset has to be divided into training and test set. The activity to be done is the same as for the previous exercise. Make sure you do not use too many values of K, as computations might take a lot of time.

Exercise 3 - User localization from RSSI

Consider the following scenario, in which we wish to localize a user employing a non-GPS system (e.g., in indoor localization). The user holds a transmission device (e.g., a smartphone or other sensor with transmission capabilities). Localization is based on measurements of the Received Signal Strength Indicator (RSSI) from *D* sensors (base stations) placed in the area in which the localization service is provided (more detailed information can be found in [1]). The area is divided into N_C square cells, and localization amounts to identifying the cell in which the user is located.



In a **training** stage, the transmission device is placed in the center of each cell and broadcasts a data packet, and RSSI is measured by each sensor. This yields one measurement, corresponding to a vector of length *D*. The process is repeated *M* times for each cell, and for all N_C cells. The training stage provides a 3-dimensional array of size $N_C DM$.

In a **test** stage, the user is located in an unknown cell. The transmission device broadcasts a data packet, and each sensor measures the RSSI and communicates it to a fusion center. The fusion center treats the received RSSI values as a test vector of length *D*. It applies a k-NN classifier, comparing the test vector with all $M \cdot N_C$ training vectors available in the training set. For each test vector, the k-NN classifier outputs the probability that each cell contains the user.

Available data: you are provided with a .mat file (`localization.mat`) containing two variables, called `traindata` and `testdata`. These variables have the same size, and are 3-dimensional arrays of size *D*=7, *M*=5, and $N_C = 24$. The 24 cells have the following arrangement:

1	2	3	4
5	6	7	8
…	…	…	…
…	…	…	…
…	…	…	…
21	22	23	24

The training data can be seen as labelled data where each cell is a class, and you are given *M* data vectors for each cell. Regarding the test data, a test vector consists of a single measurement; so each measurement has to be used individually and you can perform up to *M* tests for each cell. The data correspond to real acquisition experiments performed outdoors nearby Politecnico di Torino, using an STM32L microcontroller with 915 MHz 802.15.4 transceiver (see picture below).

Task: your task is to implement a k-NN classifier in Matlab for the classification task described above, and evaluate its performance.

Performance evaluation: The performance is defined in terms of accuracy in the localization task, and it has to be averaged over all cells. Average accuracy is defined as the posterior probability associated to the cell that the user is actually located in.