Biomedical Data Science & AI

Exercise sheet 9

SoSe2025

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Questions

Exercise 1 - Ensemble Learning (13 points)

1. Describe the key strengths of Decision Trees. Explain the disadvantages and a strategy to overcome their limitations. **(2 points)**
2. How does the Gini index help in the process of building a decision tree? Explain what the Gini index measures. What are the minimum and maximum possible values, and what do these values mean? **(2 points)**

Please use the random seed = 0 for the following exercises.

3. Using the *titanic_survival_dataset.csv*, train the following (scikit-learn) models using nested cross validation while optimizing a selected number of hyperparameters in the inner loop using grid search, then compute the probabilities of the outcomes:
    a. Random forest, optimizing the number of estimators **(2 points)**
    b. Lasso penalized logistic regression **(1 point)**
    c. Elastic net penalized logistic regression **(1 point)**

Note: Using a large parameter grid results in an extended computation time. We advise using a maximum of 5 values per hyperparameter

4. Inform yourself about calibration curves (reliability diagrams).
    a. Describe how calibration curves can explain your model's performance. **(2 points)**
    b. Use the predicted probabilities of each model from question 1 to plot a calibration curve, then explain your results. **(3 points)**

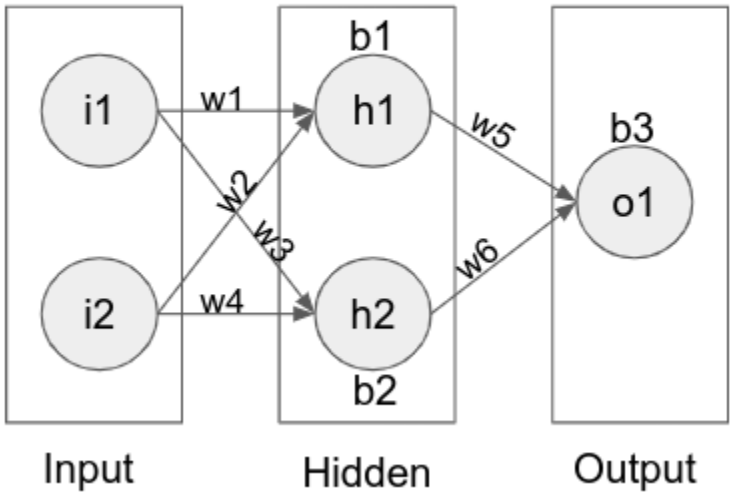
Exercise 2 - NN theoretical (12 points)

1. Suppose there is a Multi-Layer Perceptron (MLP) composed of one input layer with 5 neurons, followed by one hidden layer with 20 artificial neurons, and one output layer with 2 artificial neurons. All artificial neurons use the ReLU activation function.
    a. Deduce the shape of input matrix X, hidden layer's weight vector W_h, bias vector b_h and the shape of the network's output matrix Y. **(1 point)**
    b. Write the equation that computes the network's output matrix Y as a function of X, W_h , b_h , W_o and b_o. **(2 points)**

2. Consider the 3 layer neural network with the initial weights as given in Figure 1. Write a simple, self-contained python code to
    a. Compute the activations h1, h2, and the output o1 using the sigmoid activation function as well as the total Binary Cross Entropy loss for the expected output. **(3 points)**
    Note: b1, b2 and b3 represent the biases added to their respective units
    b. Compute the updates for the weights w1, …, w6 and bias terms b1, b2, b3 using one step of backpropagation. Assume a learning rate of 1 for the sake of simplicity. **(5 points)**
    Note: Remember that a bias term is equivalent to a weighted constant input 1.

    You should not use any other library than numpy in your code.

Figure 1



i1=0.5, i2=0.8,
w1=0.3, w2=0.33, w3=0.11, w4=0.9, w5=0.44, w6=0.55,
b1=0.8, b2=0.1, b3=0.9.
h1, h2 and o1 have activation functions as Sigmoid.
Excepted output = 1

3. What are the principal and unavoidable limitations of the backpropagation (BP) algorithm? **(1 point)**