Universität des Saarlandes
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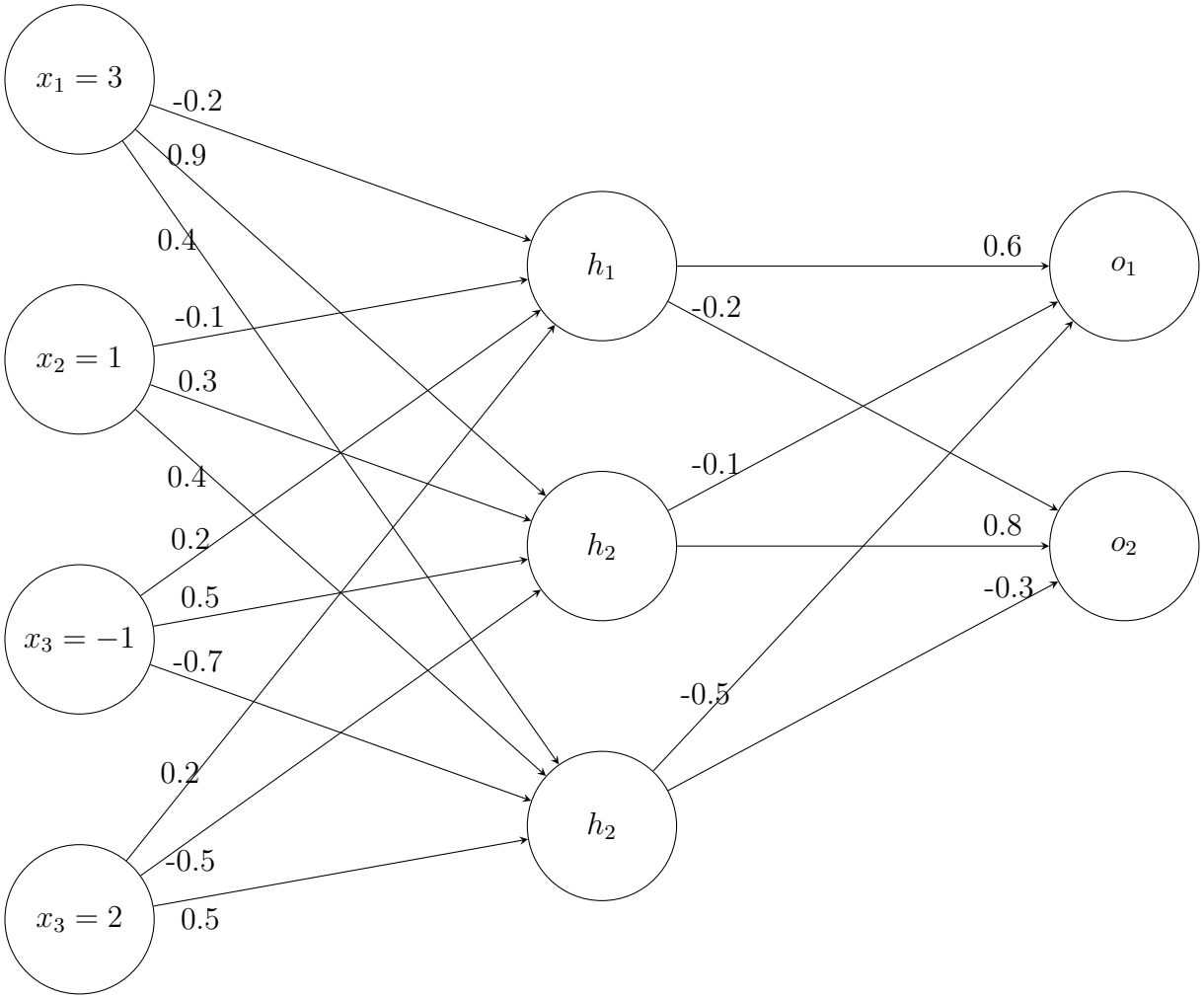
Lehrstuhl für Signalverarbeitung
NNTI Winter Term 2022/2023

Exercise Sheet 6

Neural Networks Theory and Implementation

Deadline: 21.12.2022 18:00

Exercise 6.1 - Forward Pass (Inference) and Backward Propagation (Backprop) of Errors for a Fully-Connected Neural Network (1 + 1.5 + 1.5 points)



Given above is a simple Fully-Connected Neural Network (FCNN) with one hidden layer. The input layer consists of four features (i.e., neurons), the hidden layer has three units, and the output layer with two units. We will assume Leaky ReLU as the activation function on the hidden units whereas the Softmax function on the output layer. For the sake of simplicity, we assume that there are no *bias* parameters in our network.

a) Perform one inference step (forward pass) with the given inputs and weights for the given network. State the formulae that you use throughout your computations and show all the intermediate steps involved in the calculation. i.e $h_1 = ...$, $o_1 = ...$

b) Compute all the gradients necessary for performing a backward pass. (e.g. gradient of the loss w.r.t the output, the hidden units, and the weights). You can assume Binary Cross Entropy (BCE) as the objective. Provide the formulae and computations for all the steps involved. You can use the below weight matrices and the indices of the weights in the respective matrices (e.g. $W_{23}^{(1)}$) when computing the derivatives. For other derivatives, use variables from the "Notations" given at the end of this exercise.

$$W^{(1)} = \begin{bmatrix} -0.2 & 0.9 & 0.4 \\ -0.1 & 0.3 & 0.4 \\ 0.2 & 0.5 & -0.7 \\ 0.2 & -0.5 & 0.5 \end{bmatrix} \quad W^{(2)} = \begin{bmatrix} 0.6 & -0.2 \\ -0.1 & 0.8 \\ -0.5 & -0.3 \end{bmatrix} \quad Y = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Note that Y is an one-hot encoding of the ground truth labels.

c) Perform one backward pass, update the parameters using *vanilla gradient descent* with a learning rate of 0.1, and then provide the updated weights in the same format as the given weight matrices.

Notations: When taking derivatives, you can use the following symbols for convenience.
$L(w)$ - BCE
$f(.)$ - Leaky ReLU
z_k^l - activations on the hidden layer
S - Softmax

In this exercise, you need to show step-by-step calculations. However, we recommend you to use some tools like a spreadsheet or whatever you prefer to do the calculations as it can be a bit time-consuming and messy.

Exercise 6.2 - Coding exercise (6 points)

See attached *ipynb* file

Exercise 6.3 - Reading exercise (Bonus) (3 points)

Since you have had the introduction to backpropagation, we would like you to read this paper: https://www.cs.toronto.edu/~hinton/FFA13.pdf
It empirically talks about a different approach for weight-updates in the Neural Network. The aim of this exercise is to help you develop a deeper understanding on backpropagation by doing a comparison with the methods proposed in this paper. For this exercise, please submit your insights of the paper in contrast with what you learnt in backpropagation. It's an open-ended question, and our recommendation would be that you construct your answers with your teammates collectively rather than working on it alone. You are also free to discuss with other colleagues from the class. Please keep your answer between **100-200** words.

Submission instructions

The following instructions are mandatory. If you are not following them, tutors can decide to not correct your exercise.

- Please submit the assignment as a **team of two to three** students.

- Write the Microsoft Teams user name, student id and the name of each member of your team on your submission.
- Hand in zip file containing a `single` PDF with your solutions and the completed ipython notebook. Do not include any data or cache files (e.g. __pycache__).
- Important: please name the submitted zip folder and files inside using the format: **Name1_id1_Name2_id_Name3_id3**.
- Your assignment solution must be uploaded by only **one** of your team members to the "Assignments" tab of the tutorial team (in **Microsoft Teams**). Please remember to press the **Hand In** button after uploading your work.
- If you have any trouble with the submission, contact your tutor **before** the deadline.