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1. Data manipulation with numpy **(10P)**

1.1 You can assume that numpy is already imported as *np*. Loops are generally forbidden here. We assume that a 2D array X has already been created!
a) Give a code snippet that prints the number of columns in X that have a sum bigger than 3.0
b) Give a code snippet that sets every second row of X, starting at 0, to a value of 1.0
c) Give a code snippet that sets columns 1,2 and 7 in X to 0 and uses only one assignment operation
d) Give a code snippet that computes the mean value along each column in X and prints the result.
e) Give a snippet that creates an array *Y* of dimensions [1,1,50] whose values are all -1.
f) slice 4 randomly chosen rows out of X
g) set the values at positions (1,2),(2,2) and (3,4) to 10 using a single assignment operation!
h) Assuming that the rows of X are target values in one-hot format: give a snippet that prints the number of occurrences of each class.

1. Data manipulation with numpy **(10P)** [Fortsetzung]

Fortsetzung der Frage "You can assume that numpy is already imported as *np*. Loops are generally forbidden here. We assume that a 2D array X has already been created!
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g) set the values at positions (1,2),(2,2) and (3,4) to 10 using a single assignment operation!
h) Assuming that the rows of X are target values in one-hot format: give a snippet that prints the number of occurrences of each class.":

2. Tensorflow basics **(10P)**

2.1 **a)** Explain what the method Session.run() does, what the two most typical arguments are and what it returns.
b) Give a code snippet to declare a TF placeholder of 20 rows and a variable number of columns
c) Give a code snippet to declare a TF variable that will later be initialized to a tensor of dimension [3,2] having a value of 1 everywhere**.**
d) Give a code snippet that computes and prints out the element-wise sum of two TF tensor_like objects *a* and *b* (same shape, supposed to be initialized already)
e) Assuming a TF variable *a* (supposed to be initialized to a value of [4] on the core): please explain whether or not the ouput of **print(a)** will give **[4]** as a result!
f) Given a tensor in *the NHWC data format*: how many dimensions does it generally have, and what is their interpretation for , e.g., images?
g) Explain the meaning of the term "one-hot format" for target values.

3. Advanced TensorFlow **(7P)**

3.1 **A simple CNN (7P)**

Assuming that an input placeholder X has been created already: implement (in TF) two convolutional layers, each one followed by max-pooling with kernel size 2x2. There are 11 filters of size 3x3 in the first convLayer, and 21 filters of size 5x5 in the second one.
You do not need to implement DNN layers, or loss functions, or initialize variables, or use sess.run() statements: a TF graph that computes the activities of the two convLayers is sufficient!

4. Classification and error measures **(15P)**

4.1 **Binary classification (5P)**

A binary classifier is evaluated to have a true negative rate (**tnr**) of 0.5 and a true positive rate (**tpr**) of 0.1. Compute the classification error for a dataset in which the ratio of positive to negative samples is 1:1.

$$\begin{pmatrix} 50 & 10 & 20 & 20 \\ 10 & 60 & 20 & 10 \\ 10 & 30 & 60 & 0 \\ 30 & 0 & 0 & 70 \end{pmatrix}$$

4.2 **Multi class classification (5P)**

The application of a multi-class classifer to a test set of samples yields the confusion matrix given above. Please compute:

a) The number of correctly classified samples
b) the number of samples whose true class is 3
c) the number of samples for which the classifier output is 1 or 3
d) The classification error (probability of incorrect result) under the restriction that the true class is 1
e) The classification accuracy (probability of correct result) under the restriction that the classifier output is 3

5. PCA

$$C = \begin{pmatrix} 1 & 0 \\ 0 & 5 \end{pmatrix}$$

5.1 **Eigenvectors and eigenvalues (5P)**
Given the matrix C above: show that the vector [0,1] is an eigenvector and determine its eigenvalue!

6. DNN basics **(20P)**

6.1 **CNNs (5P)**
A CNN has an input layer of size $W^{(0)},H^{(0)},C^{(0)}$= 64,64,1. We assume that 30 filters with sizes of $f_X^{(1,2)},f_Y^{(1,2)}$= 5,5 and step sizes of $\Delta_X^{(1,2)},\Delta_Y^{(1,2)}$= 1,1 are applied in layer 1 and layer 2, both times followed by max-pooling with a 2x2 kernel. Compute the dimensions $W^{(1)},H^{(1)},C^{(1)}$ and $W^{(2)},H^{(2)},C^{(2)}$ of layers 1 and 2 after max-pooling!

6. DNN basics **(20P)** [Fortsetzung]

$$\frac{\partial a_2^{(l)}}{\partial W_{32}^{(l)}}$$

6.2 **Derivatives 1 (5P)**
For an affine layer l: compute the (symbolic) derivative given above!

$$\frac{\partial a_k^{(l)}}{\partial a_j^{(l-1)}}$$

6.3 **Derivatives 2 (5P)**
For a transfer function layer l which applies the function g(x) = sin(x) to all activities in the previous layer l-1: compute the symbolic derivative specified above!

7. Discrete probabilities

Exp 1 (X):	1	2	1	2	3	3	3	2	2	2	1	1
Exp 2 (Y):	3	1	3	2	2	2	1	3	2	3	3	1

7.1 **Discrete probabilities (5P)**

Given the experimental results (above) for the two random variables X and Y: compute the following probabilities:

a) $p(X = 1)$ and $p(Y = 1)$
b) $p(X = 1, Y = 1)$
c) $p(X = 1, Y = 3)$
d) $p(Y = 1 \mid X = 2)$
e) $p(X = 1 \mid Y = 3)$

8. Advanced DNNs **(15P)**

8.1 **Fully-connected DNNs (5P)**

A fully-connected DNN has layer sizes of 3-3-5-3, where the first layer size represents the input layer. We assume that all layers are affine ones (no ReLU). Give the dimensions of all weight matrices and all bias vectors in the network and compute the total number of free parameters in this DNN!

8. Advanced DNNs **(15P)** [Fortsetzung]

8.2 **DNNs on paper (8P)**
We consider a DNN with input samples of size $Z^{(0)}$=3, followed by an affine layer with size $Z^{(1)}$=2, followed by a ReLU layer, followed by another affine layer of size $Z^{(3)}$=2. All weight matrix entries are initialized to 1, and all biases to -1: compute the activity vector $a^{(3)}$ that arises as a reaction to the single input sample $a^{(0)}$= [1, -1, -1].

8.3 **The loss function and its derivatives (5P)**
Assume that the output layer activity of a DNN is [0.3,0.7] for a single input. Compute the numerical value of the cross-entropy loss function for a target vector of [1,0], as well as the numerical values for the derivatives of the loss w.r.t. the first and second activities in the output layer.

9. Gradients and gradient descent **(13P)**

$$f(\vec{w}) = 0.5w_1^2 + 100$$

9.1 **Gradient descent (5P)**
Perform two steps of gradient descent (towards a local minimum) for the function given above, using a step size of 0.1 and an initial value of [2,2].

$$\textbf{a)}\ h(x) = 15\pi + 200\ln(e)$$
$$\textbf{b)}\ h(x) = \exp(\cos(x))$$
$$\textbf{c)}\ h(x) = \ln(x)x^2$$

9.2 **Derivatives (5P)**
Compute the derivatives of the functions given above. Please also give (where appropriate) the decomposition of each function into simpler functions, and the applicable derivative rule.

10. Extra space!!

11. Extra space!!