# Einführung in die Künstliche Intelligenz 2012S, 2.0 VU, 184.735

## Exercise Sheet 2 - Learning and Neural Networks

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**You have to tick the prepared exercises in TUWEL at the latest before Friday, 18th May 2012, 13:00 (AUFGABE Ankreuzen 2. Übungsblatt).**

**Exercise 1 (2 pts):**
Use the following data to create a *decision tree*. At each step of the construction, use a greedy approach for choosing the next attribute by maximizing the *information gain* of the chosen attributes. Give further a short overview about the performance (depth of the tree, number of correct/incorrect classifications) of your model.

| *Bsp.* | *Position* | *Type of Game* | *Premium per Goal* | *Club* | *Goal* |
|---|---|---|---|---|---|
| $X_1$ | forward | final | no | A | no |
| $X_2$ | forward | training | yes | C | no |
| $X_3$ | forward | training | no | B | no |
| $X_4$ | midfield | qualification | yes | A | yes |
| $X_5$ | defense | final | no | A | no |
| $X_6$ | defense | qualification | no | B | no |
| $X_7$ | midfield | training | yes | C | no |
| $X_8$ | forward | qualification | yes | B | yes |
| $X_9$ | defense | final | yes | A | no |
| $X_{10}$ | midfield | final | yes | C | yes |
| $X_{11}$ | forward | qualification | no | B | no |
| $X_{12}$ | midfield | training | yes | C | no |
| $X_{13}$ | defense | final | yes | A | yes |
| $X_{14}$ | forward | qualification | no | C | yes |
| $X_{15}$ | midfield | training | yes | B | no |
| $X_{16}$ | defense | final | no | B | no |
| $X_{17}$ | forward | training | yes | A | no |
| $X_{18}$ | forward | training | no | A | no |
| $X_{19}$ | midfield | qualification | yes | C | no |
| $X_{20}$ | defense | final | no | B | yes |
| $X_{21}$ | midfield | final | yes | A | no |

**Exercise 2 (4 pts):**
Use the data from Exercise 1 to create a decision tree again. This time, use a three-fold cross validation for evaluating your model. Therefore, split the instances into three sets of equal size, use two of them as training set and one as evaluation set. Then repeat this process twice, using the other sets as evaluation set and compare the different decision trees and evaluation results. Split the set randomly, e.g., by hand or by using a random number generator (see `http://www.random.org/`).

**Exercise 3 (2 pt):**
Suppose that an attribute splits the set of examples $E$ into subsets $E_k$ and that each subset has $p_k$ positive and $n_k$ negative examples. Show that the attribute has strictly positive information gain unless the ratio $\frac{p_k}{p_k+n_k}$ is equal for all $k$.

**Exercise 4 (3 pt):**
Create a full adder using an artificial neural network. Therefore, consider three input signals, $A, B$ and $C_{in}$, and two output signals, $S$ and $C_{out}$. You can use an arbitrary number of neurons and layers, but you have to describe the used activation functions and weights in detail.

**Exercise 5 (2 pts):**
A simple perceptron cannot represent parity functions of its input (e.g., XOR). Describe what happens to the weights of a four-input, hard-threshold perceptron during learning as examples of the parity function arrive. Assume that at the beginning, all weights are set to $0.1$.

**Exercise 6 (3 pts):**
Suppose you have a neural network with linear activation functions. That is, for each unit the output is some constant $c$ times the weighted sum of the inputs. For simplicity, assume that the activation function is the same linear function at each node: $g(x) = c \cdot x + d$.

(a) Assume that the neural network has one hidden layer. For a given assignment to the weights $w$, write down equations for the value of the units in the output layer as a function of $w$ and the input layer $x$, without any explicit mention of the output of the hidden layer. Show that there is a network with no hidden units that computes the same function.

(b) From your observations of Subtask (a), what can you say about a network with any number of hidden layers?