Exam in Learning Systems (DVA427)

Date	2019-03-28
Time	8:10 – 11:30
Allowed material	No
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Good Luck!!!

1. Decision Tree Learning (6+2p)

Construct the decision tree for the set of training instances in the left table with attributes x_1, x_2 and classes A, B.
1) Which attribute should be used at the root node and why?
2) Show how the examples D_1, …., D_6 are sorted down the tree and how they are classified.

Use the right table to look up the entropy for a subset of training instances. Take the entry that is closest to the decimal number for which you want to calculate the entropy (e.g. if you need to calculate the entropy of 0.33, take the entry for 0.3 in the table which is 0.9). It is sufficient to make approximate calculations rounded to one digit behind the decimal.

Training examples

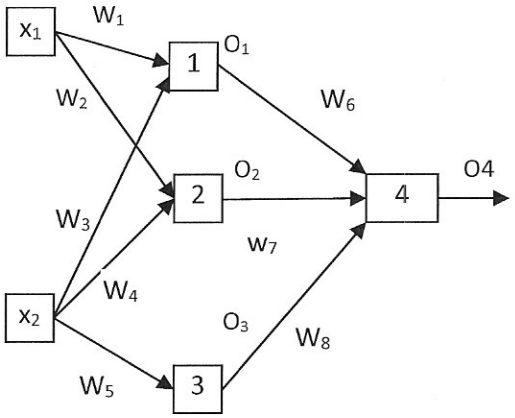
No.	x_1	x_2	$c(x_1, x_2)$
D_1	T	T	A
D_2	F	F	B
D_3	T	F	A
D_4	F	F	B
D_5	T	F	A
D_6	F	T	A

p	entropy(p)
0.0	0.0
0.1	0.5
0.2	0.7
0.3	0.9
0.4	1.0
0.5	1.0
0.6	1.0
0.7	0.9
0.8	0.7
0.9	0.5
1.0	0.0

2. Artificial Neural Network (4+2p)

Consider a neural network shown in the following figure. The outputs from the four units are given by

$$O_1 = sigmoid(w_1 x_1 + w_3 x_2 + c_1)$$
$$O_2 = sigmoid(w_2 x_1 + w_4 x_2 + c_2)$$
$$O_3 = sigmoid(w_5 x_2 + c_3)$$
$$O_4 = sigmoid(w_6 O_1 + w_7 O_2 + w_8 O_3 + c_4)$$



Now you are given a training example (x_{10}, x_{20}, t_0). Suppose that, under this training example, the outputs of the four units are O_{10}, O_{20}, O_{30} and O_{40} respectively, and the current values for weights W_6, W_7 and W_8 are W_{60}, W_{70} and W_{80} respectively. The learning rate is γ.

1) Please write out the formulas to calculate ΔW_7 and ΔW_4 in terms of the incremental BP algorithm.
2) Let $E = \frac{1}{2}(t_0 - O_{40})^2$, what are $\frac{\partial E}{\partial W_1}$ and $\frac{\partial E}{\partial c_1}$?

3. Genetic Algorithms (2+2+2+2p)

1) Suppose a population has five individuals whose fitness values are illustrated in the table as follows

Individual	Fitness
1	12
2	5
3	8
4	15
5	10

What are the probabilities of selection for these individuals?

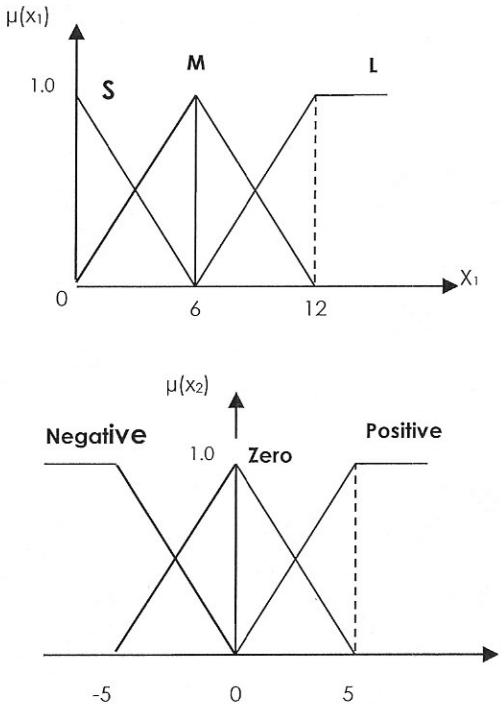
2) Now you need to select an individual from the population based on these selection probabilities. For this purpose a uniform random number from [0, 1] is created. Suppose this created number is equal to 0.7, which individual in the population will be selected according to the roulette wheel scheme and why?

3) What is the risk if a genetic algorithm has no mutation?

4) What is the difference between mutations for real-coded string and binary string?

4. Fuzzy systems and learning (4+2+1+1p)

Suppose a fuzzy classification system with two inputs x_1 and x_2. The fuzzy subsets *S, M, and L* correspond to input x_1, and fuzzy subsets *Negative*, *Zero*, and *Positive* correspond to input x_2. The fuzzy set membership functions of the inputs are depicted in the figures below.

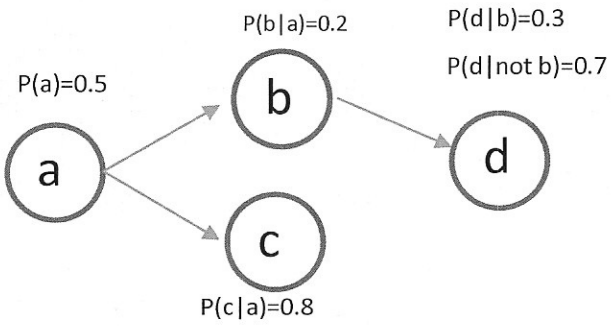


Now suppose that there are four training examples as follows:

x_1	x_2	Class
8	-2	B
2	-4	B
6	1	C
13	5	A

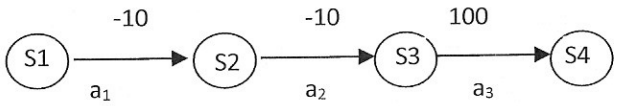
1) Please generate a fuzzy rule set from the above training examples using the Wang-Mendel algorithm.
2) What are firing strengths of the generated fuzzy rules given the input situation x_1=10, x_2=3?
3) What are the output fuzzy sets suggested by the generated fuzzy rules in the current situation with x_1=10, x_2=3?
4) How can you make final decision in terms of these fuzzy rules in the current situation with x_1=10, x_2=3?

5. Bayesian Networks (4p)
Given a Bayesian Network as follows:



What is the probability of *d* to be true when *a* is true?

6. Reinforcement learning without model (3+3p)
Given a sequence of the agent's interaction with the environment as shown in the figure as follows, where rewards are indicated above the arrows and actions are indicated below the arrows, and S4 is the terminate state.



Let Q be the estimate of the optimal action values Q*. Assume that the current Q estimates for all actions at states S1, S2 and S3 are zero.

So far the numbers of visits for the state-actions pairs $(S1,a_1)$, $(S2,a_2)$, and $(S3,a_3)$ are $N_1=2$, $N_2=5$, and $N_3=10$ respectively. The discounting factor is 0.8.

1) How can you update the Q estimates using the Q-learning rule if the environment is deterministic?
2) How can you update the Q estimates using the Q-learning rule if the environment is stochastic?