i READ THIS FIRST!

1DL073 Natural Computation in Machine Learning, home exam

Allowed help material: Inspera. It's OK to use a calculator, but it should not be strictly necessary.

Please, answer (in Swedish or English) the following questions to the best of your ability!

This is a home exam, and it is an **individual** exam! You are **not allowed to consult with any other person than me, nor look up things in books or on the Internet**.

For most questions your reasoning is very likely to be more important than the result! So please make sure that you justify your answers to the questions, unless explicity told not to. For example, if asked to compute something, show the computation, not just the result. This is why most of the questions on this exam are 'Essay' questions, to give you full access to the writing tools (including an equation editor) in Inspera. Most answers should not require more than a few sentences though.

There are 14 questions. The maximum number of points is 40. To get grade 3 (pass) a total of 20 points is required. Grade 4 requires 27 points and grade 5 requires 32 points.

I will be available on Zoom if you have questions, during the first hour of the exam. Use this link (https://uu-se.zoom.us/j/61262409782) if you have questions. Zoom will put you in a waiting room where I pick one student at a time. So just wait for your turn.

If you have more questions after the first hour of the exam, you may email me (olle.gallmo@it.uu.se). I may not be as quick to respond then though.

Good luck!

1 Match application to method

This course (and many others) divides machine learning in three sub-categories: supervised learning, unsupervised learning and reinforcement learning. To which sub-categories do the following application examples typically belong? (0.5 points for each correct mark, but -0.5 for each incorrect, so don't guess!)

	Supervised	Unsupervised	Reinforcement
Novelty (outlier) detection	○	○	○
Learning to recognize objects in pictures	○	○	○
Dimensionality reduction	○	○	○
Maximizing car traffic flow by controlling traffic lights	○	○	○
Learning to play chess as the world champion plays the game	○	○	○
Learning to play chess better than any human	○	○	○

Maximum marks: 3

2 Overfitting

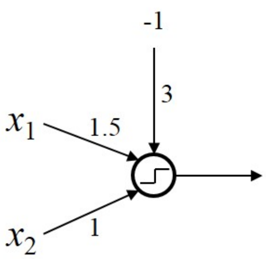
Mark below, how the risk of overfitting depends on the size of the network, the size of the training set, and for how long we train. All three must be correct for credit.

	Increased risk	Decreased risk
Increased network size (number of hidden nodes)		
Increased training set size (number of input-output samples)		
Increased training time (number of passes through the training set)		

Maximum marks: 2

3 Where is the hyperplane?

Perceptrons form hyperplanes in the input space, when used for classification. Consider the binary perceptron in the figure. Where does its hyperplane cross the x_1-axis?



Fill in your answer here

Format

Words: 0

Maximum marks: 2

4 Can you do this with a perceptron?

For which value(s) of k (if any) would it be possible for a single binary perceptron to decide if an n-dimensional binary input vector (1s and 0s) contains exactly k 1s?

Fill in your answer here

Format B I U x_2 x^2 I_x Ω Σ

Words: 0

Maximum marks: 2

5 Error plots

While training a neural network it is common to plot the error as it changes over time, both for the training set and for a separate validation set.

a) How could we typically detect, by looking at the plot for the training set, that the learning rate (η) is set too high? (2p)

b) How can we detect, using these plots, when we should stop training? (2p)

Fill in your answer here

Format B I U x_2 x^2 I_x Ω Σ

Words: 0

Maximum marks: 4

6 Compute delta-values

In the backpropagation algorithm, weight changes are computed as $\Delta w_{ji} = \eta \delta_j x_i$, where the definition of δ_j depends on if node *j* is a hidden node or an output node. Compute δ_j for the following cases:

a) *j* is a linear output node (i.e. the activation function is the identity function). It's computed node value, y_j, is 0.4. The desired output, d_j, is 1.0. (2p)

b) *j* is a logistic hidden node with steepness constant λ=1. Its weighted sum (including threshold/bias) is 0 (zero). It is connected to only one output node, and the weight of that connection is 2.0. The δ-value of the output node is 0.6. (2p)

Fill in your answer here

Format

Words: 0

Maximum marks: 4

7 Over-confidence

Consider a multilayer perceptron with sigmoidal neurons which has been trained as a classifier for a long time. Some of the nodes may then have become very 'confident' in their answers, i.e. they respond with values very close to 0 or 1.

When using Backpropagation, the weight changes for such 'confident' neurons will be very small, even if the error is large, creating a kind of trap which can be very difficult to escape. Explain why this problem occurs (2p), and why this should be less problematic for RPROP than for Backprop (1p)!

Fill in your answer here

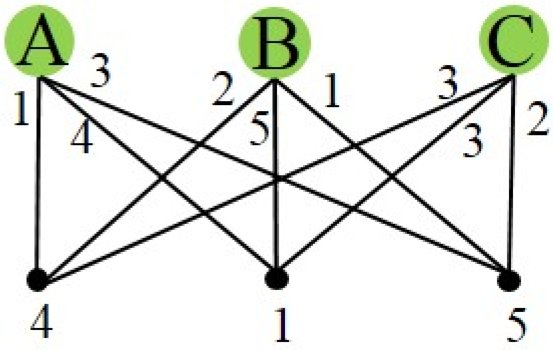
Format

Words: 0

Maximum marks: 3

8 Competitive Learning

Consider a competitive learning network of three nodes, A, B and C with weight vectors [1, 4, 3], [2, 5, 1], and [3, 3, 2], respectively. See figure.



a) Given the input vector [4, 1, 5], which node wins the competition? (Assuming Euclidean distance) (2p)

b) Given this input vector, and the winner you just identifed in a), compute new weight values for all nodes! (Assuming Standard Competitive Learning with learning rate η=0.5) (2p)

Fill in your answer here

Format

Words: 0

Maximum marks: 4

9 Growing Neural Gas

What are the three most important properties of Growing Neural Gas which makes it different from Competitive Learning or Self-Organizing Feature Maps?

Fill in your answer here

Format

Words: 0

Maximum marks: 3

10 Set the discount factor

Consider training a reinforcement learning agent on an application where you have good reason to think that decisions may have an effect up to 10 time steps ahead (actions in sequence), but probably not longer. In temporal difference learning methods, such as Q-Learning or Sarsa, this affects how you should set the discount factor, γ. What should be the best setting for γ in this case?

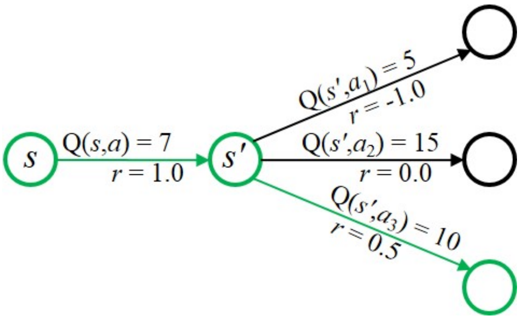
Select one alternative:

- $\gamma = 0.5$
- $\gamma = 0.8$
- $\gamma = 0.9$
- $\gamma = 0.95$
- $\gamma = 0.99$

Maximum marks: 1

11 Compute Q-values

A reinforcement learning agent is in state *s* where it decides to take an action *a* which has the estimated Q-value, Q(*s*, *a*) = 7. That action is rewarded by 1.0 and takes the agent to state *s'* where there are three possible actions with Q-values 5, 15 and 10, respectively. It selects the action with Q-value 10, which is rewarded by 0.5. See the green path in the figure.



a) What is the new value of Q(*s*, *a*) if we update it using *Sarsa*, with learning rate η = 0.1 and discount factor, γ = 0.9? (2p)

b) If we had used Q-Learning instead, it would not have mattered for the previous question which action was selected in state *s'*. Why? (1p)

c) What is the new value of Q(s, a) if we update it using Q-Learning instead? (η = 0.1, and γ = 0.9) (2p)

Fill in your answer here

Format

Words: 0

Maximum marks: 5

12 Crossover in Genetic Algorithms

Consider the four binary strings in the figure. The 'children' are the results of a crossover between the two 'parents' in a genetic algorithm. One of the conventional (named) crossover operators was used. Which one? Name it and explain what it did in this case.

parents	children
10110011	10100111
01100110	01110010

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 2

13 Particle Swarm Optimization

In Particle Swarm Optimization, why is *gbest* more likely to get stuck in suboptimal solutions than *lbest*?

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 2

14 ACO scalability

Ant colony optimization algorithms are very scalable (have low complexity) with respect to the number of ants. What is the fundamental mechanism in these algorithm, which makes them so scalable (in that respect)?

Fill in your answer here

Format B I U x_2 x^2 I_x Ω Σ

Words: 0

Maximum marks: 3