Machine Learning – January 19, 2018

Time limit: **2 hours**.

Last Name | First Name | Matricola

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Note: if you are not doing the exam ML 2017/18, write below name of exam, CFU, and academic year (when you were supposed to attend the course)

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EXERCISE 0 (points $[0, 1]$ mulitplied to the overall score of the test)

1. Write your name and matricola code in each paper you deliver.
2. Write all the answers of exercises **A** on one sheet marked as **A**, and all the answers of exercises **B** on another sheet marked as **B**. Do not mix answers of exercises **A** and **B** on the same sheet.
3. Do not use text books, slides, notes, mobile phone, laptop, etc.

EXERCISE A1

Consider a CNN with the following structure for its first two layers:

conv1 5×5 kernel and 64 feature maps with padding 2 and stride 1

relu1 acting on 'conv1'

pool1 2×2 max pooling with stride 2 acting on 'relu1'

conv2 3×3 kernel and 128 feature maps with padding 0 and stride 2

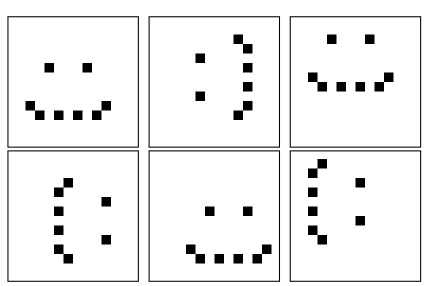
relu2 acting on 'conv2'

pool2 2×2 max pooling with stride 4 acting on 'relu2'

1. For input images of dimension $1242 \times 378 \times 3$ compute the dimensions of the volume on the output of each layer and explain how it is computed.
2. Describe what is the number of parameters of each layer.

EXERCISE A2

Consider the binary (black & white) images below defined on a 12×12 grid:



1. Explain what is the dimensionality of the data space and what is the intrinsic dimensionality of the given data.

2. Suppose you apply PCA on the data $\mathbf{x}_1, \ldots, \mathbf{x}_6$ and find that the data can be fully described using M principal components, namely $\mathbf{u}_1, \ldots, \mathbf{u}_M$. Describe how the original data can be written in the space defined by these M principal components.

3. Is M going to be equal to the number of intrinsic dimensions? Explain.

EXERCISE A3

Consider the following energy-like function defining Support Vector Machine regression:

$$J(\mathbf{w}, C) = C \sum_{i=1}^{N} L_\epsilon(t_i, y_i) + \frac{1}{2}\|\mathbf{w}\|^2,$$

with y_i, t_i target and predicted values, respectively, and $L_\epsilon(t,y) = \begin{cases} 0 & \text{if } |t-y| < \epsilon \\ |t-y| - \epsilon & otherwise \end{cases}$ the ϵ-insensitive error function.

1. Plot the ϵ-insensitive error function and explain what is the difficulty in minimizing J.

2. To overcome this difficulty slack variables ξ^+ and ξ^- are introduced. Explain (qualitatively) the role of the slack variables.

EXERCISE B1

Briefly describe a linear classification method and discuss its performance in presence of outliers. Use a graphical example to illustrate the concept.

EXERCISE B2

In Bayesian Learning, given a data set D and a hypothesis h, we can express the following relationship between the probability distributions (Bayes theorem):

$$P(h|D) = \frac{P(D|h)P(h)}{P(D)}$$

In this context:

1. define *Maximum a posteriori* (MAP) hypotheses and *Maximum likelihood* (ML) hypotheses.

2. define the concept of *Bayes Optimal Classifier*

3. discuss about practical applcability of the *Bayes Optimal Classifier*

EXERCISE B3

Describe the Markov property of Markovian models representing dynamic systems. Describe the difference between a Markov Decision Process (MDP) and a Hidden Markov Model (HMM). Draw and explain the graphical models of MDP and HMM.