Exam session 15 July 2025

509486 - Machine Learning, Artificial Neural Networks and Deep Learning

[L-31] Artificial Intelligence

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We are given a dataset containing 7000 images which are categorized into 10 classes, represented through the integers from 0 to 9. In particular:

- Each sample is a 28×28 grayscale image, with pixel values in $[0, 255]$;
- For each image class there are approximately 700 samples.

Design a deep neural network able to encode input images into a *probabilistic latent space* and then to reconstruct them back, or, alternatively, to generate new images similar to those in the dataset by sampling from the latent space. 'Reconstruct' here means that the original input image, in the input space, can be obtained back (using the trained model) from its representation in the latent space (even this one obtained using the trained model).

Take 5 minutes to think about the problem, then provide a clear answer to each of the following points. Please, write in a READABLE way.

1. MODEL. Which architecture do you consider the most appropriate for this task, and WHY;
2. INPUT. How to (if) preprocess input data;
3. MODEL CONFIGURATION.
    a Model composition: overall (graphical) outline;
    b How the image projection is modelled and realized (provide enough details);
    c How the image reconstruction is modelled and realized (provide enough details);

d How it is possible to generate new images not in the original dataset (provide enough details).

e Are there hyperparameters to be tuned?

4. OUTPUT. How would you design the output layer and why;
5. LOSS. How is the loss function designed to train your model and why.
6. MODEL EVALUATION. Describe how would you evaluate the reconstruction capabilities of the model.

HOW TO ANSWER: Motivate your choices. Povide technical/mathematical descriptions when suitable. Writing more does not necessarily imply a higher evaluation, in general. Be precise.

Dedicate an answer to each of the points above (1-6), **maintaining the same numbering format, even for subitems**.

Please leave SPACE after each point. Insert line breaks to help readability.

During the exam, the use of electronic devices, including mobile phones, tablets, smartwatches, etc., is strictly prohibited. Any detected instance of misconduct will be appropriately sanctioned and recorded in the student's academic record.

You will have time till July 23rd, 23:59, to upload the implementation of your solution in a Colab notebook. The notebook should totally adhere to the proposed solution. On the web page of the course you will find a link with the instructions on how to submit your solution. At the same link, after the exam, you will also find the abovementioned data to be used for the implementation.

If no file is uploaded, the exam is considered as rejected. In case of problems in uploading your solution, write for the teacher BEFORE the above-mentioned deadline for delivering.