FACULDADE DE
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Advanced Machine Learning
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Did you see that sign?

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1 Introduction

We present here the first practical project, part of the students' evaluation process of the Advanced Machine Learning course of the Master in Engineering and Data Science of the University of Coimbra. This work is to be done autonomously by a group of **two students**. The **deadline** for delivering the work is **7 Abril** of 2024 via Inforestudante. The quality of your work will be judged as a function of the value of the technical work, the written description, and the public defence. All sources used to perform the work (including the code) must be clearly identified. The document may be written in Portuguese or in English, using a word processor of your choice[1]. The **written report** is limited to **8 pages long** The document should be well structured, including a general **introduction**, **a description of the problem**, the **approach**, the **experimental setup**, an **analysis of the results**, and a **conclusion**. The report should follow the Springer LNCS format. The Latex and Word templates are available in the Support Material of the course. The final mark will be given to each member of the group individually. To do the work the student may consult any source he/she wants. Nevertheless, plagiarism will not be allowed and, if detected, it will imply failing the course. While doing the work and when submitting it, you should pay particular attention to the following aspects (whose relative importance depends on the type of work done):

- description of the approach to the problem
- description of the general architecture of the methods used;
- description of the experiment, including a table with the parameters used which should allow full replication;
- description of the evaluation metrics used for the validation: quality of the final result, efficacy, efficiency, diversity, or any other most appropriate;

Do not forget, besides what was just said, that it is fundamental: (1) to do a correct experimental analysis; (2) to do an informed discussion about the results obtained; (3) to put in evidence the advantages of the chosen alternative.

[1] Latex is preferred

2 Problem Statement

Image classification is a computer vision problem where Machine Learning has obtained impressive results. In the past to tackle this task practitioners had to use expert knowledge and perform feature engineering, carefully crafting and creating visual features for Machine Learning models to learn. After this step, classical and shallow models were usually employed such as Adaboost, RandomForests, Support Vector Machines, and Multi-layer Perceptrons.

Despite making their first appearance in the late 80s early 90s, Convolution Neural Networks (CNNs) became popular since 2010 due to technological advances, namely in GPU computing, and have been heavily used for image classification problems with great success surpassing most classical approaches. The main feature that this type of Artificial Neural Network provides is that feature extraction and learning is an integral part of the neural network, performing automatic feature extraction using the whole image as input, where the features are then passed to dense layers, providing the classification power as typical fully connected Multi-Layer Perceptrons are able to.

In this work, we are going to tackle an image classification dataset of traffic sign images using Artificial Neural Networks (ANNs).

3 Objective

The main objective is to analyse the dataset and create a machine learning approach with neural networks as the models that can perform supervised image classification of the dataset that is address in Section 3.1. To do that you should attend to the following objectives:

- Prepare the machine learning pipeline for the image classification dataset.
- Explore solutions and compare the results using at least, the following ANNs models:
  - Multi-Layer Perceptrons (MLP)
  - Convolutional Neural Networks (CNNs)

- And for each model, experimentation with different layer architectures, loss functions, optimisers and hyperparameters. Explore at least:
  - Loss function: MSE, Cross Entropy
  - Optimizers: RMSprop, Adam

Exploring other solutions than the listed ones that are suitable for the problem at hand and considered as extra work, can be as compensation points to cover problems in the listed ones above.

3.1 Dataset

The dataset is based of the "Traffic Sign Dataset" with 54 different classes. For this work we will work with the dataset at the $75 * 75$ **pixel resolution** and a subset of **9 classes** that are the following:

6 - Speed limit (70km/h)

12 - Don't go left or right

13 - Don't go right

24 - Go right

37 - Children crossing

38 - Dangerous curve to the right

39 - Dangerous curve to the left

44 - Go left or straight

50 - Fences

Figure 1 shows an example of the dataset. The dataset set is composed of 518 images, with different distribution of examples per class.

Folders containing the images of each class in the dataset are provided. The main goal is to use this data to design, implement and validate your approaches and the test will be used to evaluate the generalisation ability of your models through a Kaggle competition (check Section 4).

Figura 1: One example of each class from the training dataset.

3.2 Evaluation Metrics

Given the training dataset, you should split it into train, validation, and test to see how to fit the models that you are training/creating. Thus, the validation part of this work is crucial and you should select the most appropriate set of metrics and justify them.

4 Competition

To evaluate the generalisation ability of the developed models, we are going to use a Kaggle competition. Note that it will not impact the final mark but rather will act as a way for you to access the progress you are making and evaluate the generalisation performance of your models. The competition is available at the following address:

https://www.kaggle.com/competitions/aml-2024-project1

To participate in the competition, you should prepare a csv file with two columns: the first column contains the Id of the sample that you are classifying, and the second column should contain the corresponding classification label. An example of a submission file is provided along with the project statement.

5 Conclusion

A few short comments. First, the control of the progression of your work will be done during the classes (T and PL). Moreover, you can discuss eventual problems by presenting yourself during office hours. Second, the projects reflect for the most part your actual knowledge. The rest will be the object of lecturing soon after Easter. Third, we try to balance the difficulty of all the work, but we are aware that this is not an easy task and it is somehow a subjective matter. Fourth, we try to ask for a workload compatible with the value of the work for the final mark.

Methodological issues, like the statistical background, were elucidated during the previous lectures. You may use the statistical tool you feel at ease with, including the Python code that was provided. Finally, even if this is a work that asks you to do simulations and analyse the results, i.e., it has a practical flavour, there is however a theory behind the work, and you are advised to consult the necessary literature.

Good luck!