ML in Fundamental Physics

Ludwig-Maximilians-Universität München

Prof. Dr. Dieter Lüst, Dr. Sven Krippendorf, Summer Term 2020

Practical Exam

Practicalities

- You can start working on this exam right away when you receive it.
- Please note on each file you submit your candidate number. You can find your candidate number at the bottom of the pages.
- The maximum number of points in this exam is 40 points.
- The total points required for passing, from both this theoretical and the practical part, is expected to be around 50 points. The minimum requirement from each part is 20 points.
- The submission is via the course's Moodle website. The deadline for submission is 18:00 on Tuesday (4th). You can submit up to 20 files. Each file cannot be larger than 50MB.
- In case of technical problems or questions, there is a zoom meeting with ID: 926 9784 1705 (PW: 636741). This is our standard course zoom meeting ID for Monday. Note that in case of internet failure, you can join this meeting via phone.
- I intend to be available on this meeting on Monday from the start until 5pm. On Tuesday, I will be available from 9am-11am and 1pm-6pm (finish of the exam). You can also email me during the exam with questions or problems.
- For safety, please retain a copy of your answers.
- We will check your submissions after the deadline. In case of technical problems, we will be in contact via email.

Rules and Declaration

You have to perform this exam by yourself and you are not allowed to help other students in their exam of this course. In particular, this means that communicating and sharing answers with other students during this written exam is not allowed. Communication with other people on topics covered in this exam is not allowed during the examination period.

By signing below, you indicate that you obeyed these rules and that you understand that you can be prosecuted in case of violation of these rules.

Munich, 04.08.2020, Luca Schinnerl, 11545978

Place, Date, Name, Student-ID number (Matrikelnummer)

Request for Extension

In case you have an exam during the period of this practical exam, you can request a time extension for the duration of this exam. Please let me know via email about the extension you need. In addition, please fill in the below: I request an extension for __________ hours. The following exam is in parallel to this exam:

Lecture course: ____________________

Course instructor: ____________________

1 Data

You can find a dataset on the Moodle website (ising_data.zip). These are some Monte Carlo samples of the standard ferromagnetic 2D Ising model on a square lattice of size 40x40 generated at different temperatures. For each temperature there are 1001 spin configurations. The factor indicates how close it is to the critical temperature (e.g. 1 corresponds to $0.1\beta_c$, $\beta_c = 1/(T_c k_B)$).

It contains various numpy arrays and the code snippet (Code_snippet.ipynb) on the Moodle website might be helpful to read in the data and to perform simple checks (e.g. calculating the energy and magnetization of the configurations).

2 Comparing neural network classifier and Random Forest Classifier

- Generate appropriate datasets (training and validation set) for binary phase classification.
- Generate a dimensionally reduced datasets (training and validation set, using 20 dimensions) for binary phase classification utilising PCA.
- Build a feed-forward neural network utilising mostly **Dense layers** which can be used to classify the phases in the 2D Ising model. Your analysis should have two types of networks, one taking the original spin configuration as an input and the other taking the dimensionally reduced configuration as an input.
- Build a feed-forward neural network utilising a **convolutional architecture** which can be used to classify the phases in the 2D Ising model. Your analysis should have two types of networks, one taking the original spin configuration as an input and the other taking the dimensionally reduced configuration as an input.
- Build a Random Forest classifier (sklearn) to detect the low and high temperature phase of the dataset you are given. Your analysis should have two types of classifiers, one taking the original spin configuration data as an input and the other taking the dimensionally reduced configuration as an input.
- Compare the performance of all approaches utilising the best architecture you have found in the previous questions. Performance refers to accuray on the training and validation set, as well as the training speed.

Guide for documentation

Your documentation shall describe your experiments (in particular this shall include the choices of hyper-parameters and how the performance changes when you vary the hyper-parameters). Provide a justification for your choices of hyper-parameters. Your documentation should not be longer than 1000 words. Code snippets, equations, and figures do not count towards the word count.

In case your code does not show the desired results (e.g. you observe mode collapse in GANs), comment on how you have tried to address it. If time does not permit an extensive improvement, comment on the possible further steps.

Guide for code submission

Your code should be run-able. For your best performing neural networks, you should submit your model weights. This allows us to reproduce and check your results.

Weighing of coding and documentation

The code and documentation take roughly equal weight overall. This does not necessarily hold for each individual item.

In case networks do not converge, your documentation of your results carries more weight. **Full points do not require perfect numerical results:** This means that only a reasonable attempt at tuning hyper-parameters is required. However, full points require that your attempts are well documentated and described.