PHY496 Machine Learning for Physics Research

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Time: Tuesday and Thursday, 15:00-16:15 Eastern US time

Course Description

The course is addressed to graduate students familiar with data analysis methods as typically taught in science labs, but who have little or no familiarity with machine learning. It will provide an overview of machine learning methods as used in physics, and more broadly science, research. It introduces the main concepts, methods and python libraries for machine learning, emphasizing practical training through examples.

Course Contents

1. Introduction. Types and Challenges of Machine Learning in Physics.
2. Working with python, Jupyter Notebooks and Machine Learning Libraries.
3. Classification. Training of Models.
4. Support Vector Machines. Decision Trees.
5. Ensemble Learning. Random Forests.
6. Dimensionality Reduction. Principal Components Analysis.
7. Deep Learning Basics. Architectures of Deep Networks. Optimization of Parameters.
8. Fully Connected Networks.
9. Convolutional Neural Networks. Recurrent Neural Networks. Graph Networks.
10. Introspection. Uncertainty and Robustness. Design of Objective Functions.
11. Weakly-supervised Classification. Autoencoders. Generative Models.

Initial Competences

- Data analysis methods as typically practiced in undergraduate science labs
- Basic scientific programming concepts and skills.
- Some experience writing scripts or small programs, basic use of command line.

Final Competences

- Ability to select machine learning method to analyze data.
- Ability use classical machine learning tools and libraries.
- Ability to select and train deep neural network models.
- Knowledge of strength and shortcomings of machine learning methods.

Office Hours and Individual meetings

Office Hours to be determined during the first meeting. I will also be available for individual meetings (through zoom or in person).

Textbooks

Both textbooks are available as free ebooks through Lehigh University libraries.

Martin Erdmann, Jonas Glombitza, Gregor Kasieczka, Uwe Klemradt, "Deep Learning for Physics Research," World Scientific, 2021

Aurélien Géron, "Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow," third edition, O'Reilly, 2022

Grading

The course grade will be based on:
1. Homework problems (50%). The homework problems will be data analysis exercises using python. Since practical training is one of the main aims of the course, students will be expected to devote a significant amount of time on the homework every week. Students will receive at least 50% for effort on each problem.
2. Class Participation and Quizzes (10%).
3. Final Project (40%).

Accommodations for Students with Disabilities:
Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online

at https://studentaffairs.lehigh.edu/disabilities.

The Principles of Our Equitable Community:
Lehigh University endorses The Principles of Our Equitable Community (http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf). We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.