Machine Learning in Lattice Gauge Theory

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Topics to be covered

- ❖ Basics on Machine Learning
- ❖ Phase Transition in Lattice Gauge Theories
- ❖ Renormalisation Group and Machine Learning
- ❖ Machine Learning for Quantum Field Theories with sign problem
- ❖ Machine Learning and Spectral Functions in Lattice QCD
- ❖ Flow Based Sampling
- ❖ Machine Learning and Effective Field Theories
- ❖ Estimation of Lattice QCD observables using Machine Learning

Proposed Syllabus – The basics

- ❖Basic Structure of Artificial Neural Networks
- ❖Training a Network
- ❖Supervised Learning
- ❖Convolutional Neural Networks
- ❖Unsupervised learning
- ❖Recurrent Networks
- ❖Transformers
- ❖Boltzmann Machines
- ❖Support Vector Machines
- ❖Reinforcement learning

Proposed Syllabus – Phase transitions

- ❖Supervised and Unsupervised phase transition recognition in Spin Models
- ❖Examples of Applications in LGT
  - ❖Phase transition recognition in SU(2) (Sebastian Wetzel)
  - ❖Phase transition recognition in SU(3) (Denis Boyda)
  - ❖Phase transition recognition in Lattice QCD (Maria Paola Lombardo)

Proposed Syllabus – Renormalization Group

- ❖Machine Learning and Renormalization Group (Youtube lectures)
- ❖Deep Learning and Renormalisation Group (Youtube lectures)
- ❖Inverse Renormalisation Group in Lattice Field Theories (Dimitrios Bachtis)

Proposed Syllabus – Machine Learning for Quantum Field Theories with sign problem

- ❖Contour Deformations (Thomas Luu, Michael Wagman)
- ❖Complex Normalizing Flow (Yukari Yamauchi)
- ❖Applications

Proposed Syllabus – Machine Learning for Spectral Reconstruction

- ❖ Machine Learning and the Inverse Problem
- ❖ Machine Learning Hadron Spectral Functions In Lattice QCD (Heng-Tong Ding)
- ❖ Applications

Proposed Syllabus – Flow Based Sampling

- ❖Normalizing Flows (Elia Cellini)
- ❖Stochastic Normalizing Flows (Elia Cellini)
- ❖Fourier Flows (Lingxiao Wang)
- ❖Equivariant Flows (Matteo Favoni, Daniel Schuh, Phiala Shanahan)
- ❖Applications

Proposed Syllabus – Effective Field Theories

- ❖Symbolic Computation using Machine Learning (Abdulhakim Alnuqayqdan)
- ❖Bayesian estimates for high orders in perturbation theory (Aleksas Mazeliauskas)
- ❖Generative models in Effective Field Theories (Marina Marinkovic)
- ❖Differentiable programming in Effective Field Theories (Fernando Romero-Lopez, Phiala Shanahan)

Proposed Syllabus – Estimation of Lattice QCD observables using Machine Learning

- ❖ Boosted decision tree regression ML algorithm (Boram Yoon)
- ❖ Single Point Neural Networks & Global Neural Networks(Giovanni Pederiva)

Pre-existing Material

- ❖The basics by Florian Marquardt: http://machine-learning-for-physicists.org/
- ❖Introduction to Machine Learning Approaches for Simulating Lattice Field Theories, by Lena Funcke – Lattice Practises 2021 - https://indico.cyi.ac.cy/event/1/timetable/#20211012
- ❖Machine Learning for Lattice QCD, by Phiala Shanahan – INT Summer School on Problem Solving in Lattice QCD
- ❖Many general presentations on Machine Learning for Lattice QCD can be found online - however **not** lectures
  - Phiala Shanahan - YouTube
  - Kurtej Kanwar - YouTube
- ❖The basics exist in several lectures
- ❖Need to create lectures from scratch - ask volunteers

Pre-requisites

- ❖Basic Data Science skills
- ❖Computational Skills – Programming languages,

People involved so far in Machine Learning

❖Andreas Athenodorou

❖Davide Vadacchino

❖Maria Paola Lombardo

❖More to follow after discussions in

Machine Learning approaches in Lattice QCD - An interdisciplinary exchange

- Week 27 February 2023 to 3 March 2023
- Covers a broad range of applications