Scientific Area	High Energy Physics		
Project Title	Machine learning techniques applied to lattice gauge theories		
Recruiting Institution	The Cyprus Institute		
PhD awarding Institution	The Cyprus Institute	**PhD Duration**	36 Months
Supervisor/Institution	Giannis Koutsou, The Cyprus Institute		
Co-Supervisor/Institution	Karl Jansen, DESY-Zeuthen, Jacob Finkenrath, The Cyprus Institute		
Secondment(s)	DESY-Zeuthen		

Project Description

The project aims in applying machine learning techniques to the study of lattice gauge theories. We will explore methods such as generative flows to be used to sample configurations directly from a known probability density, methods for improving statistical accuracy of correlation functions, such as via determining path integral contour deformations with machine learning, and generalizations of Hybrid Monte Carlo (HMC) that use deep neural networks to improve sampling.

Several such techniques have been proposed in the literature recently, so far applied to proof-of-concept problems and have been shown to address critical slowing down and large autocorrelations that appear near critical points of a phase transition. Their applicability and scalability to more complex systems such as QCD however remains an open question.

Within this project, the engaged student will study these techniques and in particular their scalability and applicability to lattice QCD. The student will apply generative flows to simple models, such as φ^4 theory and the Schwinger model and study their scalability as the problem size increases and as these systems approach critical points. Domain decomposition techniques will be adapted to generative flows for improving performance as the volume is increased, as well as for treating fermions in the Schwinger model. Applications of similar approaches to standard sampling techniques, such as the HMC will be studied using the same models. After benchmarking these approaches, we will study them for lattice QCD starting with small lattices.

Furthermore, to efficiently use such methods for problem sizes relevant to state-of-the-art lattice QCD simulations, the student will implement these models in parallel machine learning frameworks in order to scale training and inference on large-scale computational resources, such as supercomputers equipped with GPU nodes.

Project Objectives

The objectives are to study the machine learning techniques outlined above and in particular:

- Determine their scalability with the problem size for a select set of systems
- Determine their potential to mitigate critical slowing down by evaluating their performance as a critical point is approached compared to traditional simulation methods
- Study these methods for the case of lattice QCD, thus requiring their implementation in distributed codes that can span multiple compute nodes

Required Candidate Qualifications

- BSc (or equivalent) in physics
- MSc (or equivalent) in computational science, nuclear or particle physics, or a related field

Candidates with a strong Theoretical Physics background and a keen interest in lattice quantum field theories and computational skills will be favoured.