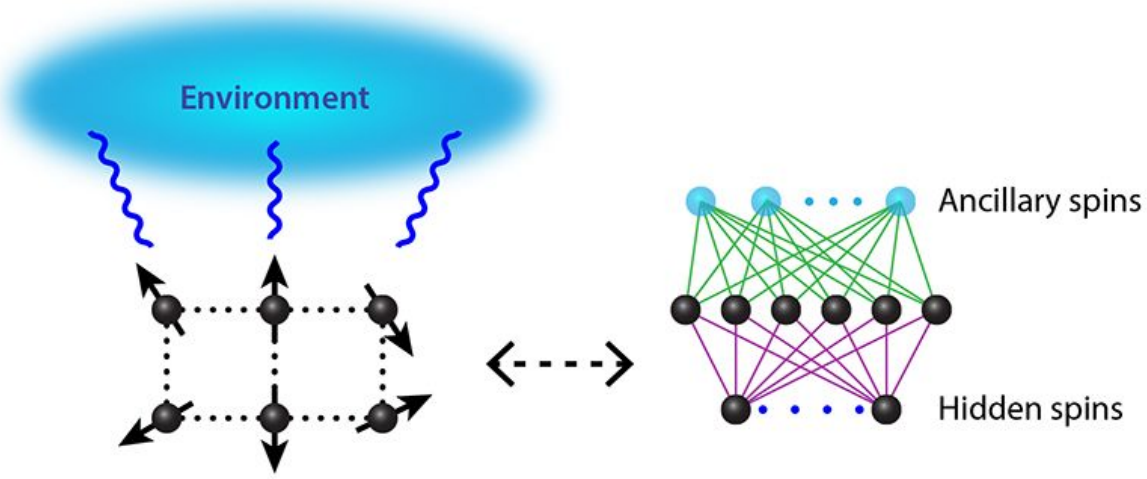
TITLE: Machine learning approaches to modeling open (quantum) systems

Supervisors and coaches: Corneel Casert, Tom Vieijra, Jannes Nys, Jan Ryckebusch
Research group: Theoretical Nuclear Physics and Statistical Physics

General Context



Machine learning and deep learning have recently provided a multitude of generic tools to tackle issues connected with analyzing and organizing data in high-dimensional spaces (often with hundreds or even thousands of dimensions). For many years, the so-called curse of high-dimensionality has plagued many researchers across various fields and applications. As it offers opportunities to beat this curse, machine-learning algorithms have recently seen a sharp increase in scientific applications involving many dimensions. Research on the physics of strongly correlated systems is one of the domains where the applicability of machine learning is currently being explored in a worldwide effort of many research groups. A seminal paper by Carleo and Troyer has illustrated the potential of these algorithms for quantum physics. The state of quantum systems can be formally described in terms of probability amplitudes, also known as wave functions. More specifically, we aim to model the probability amplitudes $\Psi(\mathbf{x})$ in $|\Psi\rangle = \sum_{\mathbf{x}} \Psi(\mathbf{x}) |\mathbf{x}\rangle$ efficiently, where $|\mathbf{x}\rangle$ represents the chosen basis states.
Understanding how systems behave when they couple to the environment is crucial in practical implementations of quantum information. Recently, the formalism of using machine learning to study quantum closed systems has also been applied to open quantum systems. Hereby, one models the density matrix, rather than the probability amplitudes.

- Machine learning for closed quantum systems (Carleo and Troyer): https://arxiv.org/abs/1606.02318

- Machine learning for open quantum systems, an introduction and overview: https://physics.aps.org/articles/v12/74?fbclid=IwAR2hVTFReQA-3ITNQXKEAtQN7KQ5Lz41wyM19DJDtS1H4fLDNivqxqh5G2k
- Recent research from our group: https://arxiv.org/abs/1905.06034

Research goals of the MSc thesis

In a recent publication (LINK) we have studied machine learning applications for closed quantum spin systems. The scientific goal of the MSc thesis is to study **open** (quantum) systems using machine learning approaches. The thesis consists of an elaborate literature study, followed by the development of a simulation code. The code will be used to conduct a comparative study of state-of-the-art machine learning techniques and their performance on open systems.

We are seeking a creative student with an outspoken interest in Theoretical (Quantum) Physics and Statistical Physics who wishes to work on a project that combines analytical with numerical work. This thesis will also require elaborate literature searches.

Mobility options

We can seek with interested students for suitable summer schools. An example of a suitable summer training might be: https://indico.ectstar.eu/event/72/