Neural Network study on 2d scalar field theory

Kai Zhou[1]

[1]Frankfurt Institute for Advanced Studies - Goethe-Universität, Frankfurt, Germany

We explore the perspectives of deep learning techniques in the context of quantum field theories. In particular, we discuss complex scalar field theory at nonzero temperature and chemical potential - a theory with a nontrivial phase diagram. With deep learning, a neural network is successfully trained to recognize the different phases of this system and predict the value of various physical observables (particle density and the squared field), based solely on the field configurations from Monte-Carlo generation. It's found that the network is robust and able to recognize patterns with limited training examples and can generalize well to different chemical potential, thus has the ability to do non-linear interpolation being in according with underlying physics from training. We then further explored the modern deep learning technique GAN (generative adversarial neural network) to help generating new configurations in the sense that typical thermal observables to be consistent with the Monte-Carlo generation. This method can bypass the conventional Markov-Chain Monte-Carlo process and thus computationally efficient and memory light compared to traditional approach.

In both physics (heavy-ion collisions) and valve-industry, we investigated using deep learning to detect bulk properties during a dynamical evolution process from final approachable observables or acoustic records.

In heavy-ion collisions, we devoted a new method using deep learning to construct an equation-of-state (EoS) emter to better understand QCD matter created from heavy-ion collisions provided the final pion's spectra. Within hydrodynamical evolution which is simulating heavy-ion collisions we clearly demonstrated there do exist encoders from QCD transition information (cross-over or first order) onto the final particle spectra, and the deep convolutional neural network is capable of finding out this encoder and thus can disentangle different hidden correlations (from unknown physical factors like initial conditions, equilibrium time, transport coefficients and freeze-out temperatures) to efficiently provide mapping between the phase transition information during dynamics to the final output particle spectra. This thus can provide us an useful tool to unveil knowledge from highly implicit data of heavy-ion experiments.

In valve-industry, we conducted 'Smart Valve' project with industry collaborators aiming at giving normal valve ability to communicate. In the first step we take similar strategy as above, using deep learning to analyze the working state (to detect cavitation/turbulent flow status, to estimate the flow velocity inside the valve, to tell if there's leakage) based on acoustic signal from valve. This can save a lot of manpower and help doing anomaly detection and safety insuring for valve/pipe plants like underground or large-scale industrial devise.