FM 79: Entanglement: Neural Networks for Many-Body Dynamics

Time: Thursday 14:00–15:30 Location: 2004

FM 79.1 Thu 14:00 2004

Quantum many-body dynamics with neural network states — •Markus Schmitt[1] and Markus Heyl[2] — [1]Department of Physics, University of California, Berkeley, USA — [2]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

The growth of entanglement during the non-equilibrium dynamics of quantum many-body systems constitutes a major challenge for numerical simulations on classical computers. We explore the possibility to compress the many-body wave function using artificial neural networks as a versatile approach for the efficient simulation of quantum dynamics. This method allows us to study two-dimensional systems far from equilibrium, which are realized, e.g., in quantum simulators based on ultracold atoms or Rydberg atoms. In our discussion we include subtleties of the time evolution algorithm and ways to assess the accuracy of the results.

FM 79.2 Thu 14:15 2004

Quenches near Ising quantum criticality as a challenge for artificial neural networks — •Martin Gärttner, Stefanie Czischek, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Heidelberg

The near-critical unitary dynamics of quantum Ising spin chains in transversal and longitudinal magnetic fields is studied using an artificial neural network representation of the wave function. A focus is set on strong spatial correlations which build up in the system following a quench into the vicinity of the quantum critical point. We compare correlations obtained by optimizing the parameters of the network states with analytical solutions in integrable cases and time-dependent density matrix renormalization group (tDMRG) simulations. The neural-network representation is shown to yield precise results in a wide parameter regime. However, for quenches close to the quantum critical point the representation becomes inefficient. For nonintegrable models we show that in regimes where tDMRG is limited to short times due to extensive entanglement growth, also the neural-network parametrization converges only at short times.

FM 79.3 Thu 14:30 2004

Many body quantum states and neural networks — •Felix Behrens, Stefanie Czischek, Martin Gärttner, and Thomas Gasenzer — Kirchhoff Institute for Physics Heidelberg

our goal is to represent quantum systems with neaural networks. doing this in a naive way, two major problems which naturally arise are inherent for quantum systems. these are the complex valued probability amplitudes and the exponential scaling of the hilbert space.

operator valued measures (povm) are the tool to map density matrices of abritrary quantum systems to probability distributions in an invertable way. after performing povm measurements, all degrees of freedom are positive real valued numbers. these probabilities are the fundamental link to machine learning systems in general and restricted boltzmann machines (rbm) in our investigations. using these systems (rbm) as generative models for informationally complete quantum measurements feature approximations with polynomially many parameters and allow efficient calculation of expectation values. in this talk, I will present a way how to map the time evolution of a density matrix under a given hamiltonian to a linear evolution equation for the probability distribution in the context of povm.

FM 79.4 Thu 14:45 2004

Efficient training for neural-network quantum states — •Sheng-Hsuan Lin and Frank Pollmann — Department of Physics, T42, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany

Neural networks have been demonstrated to be a promising approach to represent many-body quantum states. However, this approach suffers from difficulties in optimization for realistic models for two main reasons: Inefficiencies in the Markov chain Monte Carlo sampling procedure and the high cost for the stochastic reconfiguration procedure in variational Monte Carlo method. Recently, it has been shown that neural autoregressive quantum states, which are motivated by the architecture known as autoregressive models, lead to an efficient direct sampling procedure which overcomes the first difficulty. Here we consider the approximated second order method proposed in the machine learning community to investigate the possibility to overcome the second difficulty. We benchmark our algorithm by considering the frustrated J1-J2 model on the square lattice.

FM 79.5 Thu 15:00 2004

Emergent Glassy Dynamics in a Quantum Dimer Model — •Johannes Feldmeier, Frank Pollmann, and Michael Knap — Department of Physics, Technical University of Munich, 85748 Garching, Germany

We consider the quench dynamics of a two-dimensional quantum dimer model and determine the role of its kinematic constraints. We interpret the non-equilibrium dynamics in terms of the underlying equilibrium phase transitions consisting of a BKT-transition between a columnar ordered valence bond solid (VBS) and a valence bond liquid (VBL), as well as a first order transition between a staggered VBS and the VBL. We find that quenches from a columnar VBS are ergodic and both order parameters and spatial correlations quickly relax to their thermal equilibrium. By contrast, the staggered side of the first order transition does not display thermalization on numerically accessible timescales. Based on the model's kinematic constraints, we uncover a mechanism of relaxation that rests on emergent, highly detuned multi-defect processes in a staggered background, which gives rise to slow, glassy dynamics at low temperatures even in the thermodynamic limit.

FM 79.6 Thu 15:15 2004

Quantum computing and neural networks: a topological approach — •Torsten Asselmeyer-Maluga — German Aerospace Center (DLR), Rosa-LUxemburg-Str 2, 10178 Berlin, Germany

A neural network but also the brain can be seen as a dynamical graph of neurons with electrical signals having amplitude, frequency and phase. Because of the complexity of the graph, it is hopeless to include the whole graph. Instead we form areas of neurons having the same state (ground state or excited state). We describe the interaction between these areas by closed loops, the feedback loops. The change of the graph is given by deformations of the loops. At first view, the neuron area interaction as represented by loops cannot be neglected. Then it can be shown that the set of all signals forms a manifold (character variety). In the talk, we will discuss how to interpret learning and intuition in this model. Using the Morgan-Shalen compactification, the limit for large graphs can be analyzed by using quasi-Fuchsian groups as represented by dessins d'enfants (graphs to analyze Riemannian surfaces). These dessins d'enfants are a direct bridge to (topological) Quantum computing with permutation groups. The normalization of the signal reduces the group to SU(2) and the whole model to a quantum network. Then we have a direct connection to quantum circuits. This network can be transformed into operations on tensor products of states. Formally, we obtained a link between machine learning and Quantum computing.