Title: Generalized tensor methods and entanglement measurements for strongly correlated systems

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In this series of lectures we start at a very elementary level introducing main concepts and cover the more advanced approaches during the last lecture. Due to time constraint only some selected topics will be included but references to important reviews will be given. Examples covered in the Exercise are planned to help students to learn some basic technical aspects of the methods.

Some related materials can be taken from:
http://tagung-theoretische-chemie.uni-graz.at/en/workshop-2014/
http://tagung-theoretische-chemie.uni-graz.at/en/past-workshops/workshop-2014/

Lecture-1. Introduction to lattice representations

Definition of lattices, basis states, representations, etc..
Numerical methods and concepts using exact diagonalization, i.e., finite temperature, dynamics, iterative diagonalization methods (Lanczos, Davidson) etc.

Lecture-2. Iterative methods and approximations

Block renormalization group (BRG), scaling, fix point, etc.
Numerical renormalization group (NRG).
Schmidt decomposition, density matrix renormalization group (DMRG), real space, momentum space, long-range interactions.
Matrix product state (MPS) representation, matrix product operator

representation (MPO). NRG revisited: density-matrix numerical renormalization group (DM-NRG) method.

Lecture-3. Entanglement and higher dimensional networks

Tensor factorization, basic concepts of quantum information theory, entanglement, tensor network states (TNS), entanglement based optimization procedures, quantum phase transition using quantum information theory, entanglement based optimization of basis etc.
Data sparse representations.

Lecture-4. More advanced concepts:

Relationships between reduced density matrices, correlation functions and entanglement.
Mutual information, Kullback-Leibler entropy, time evolution, finite temperature entanglement spectrum, etc
Entanglement and g-ology.
Some technical aspects: parallelization, cpu/gpu approaches.

Lecture-5. Exercise:

We determine scaling equations for the ITF model (Ising model in transverse magnetic field) using the BRG method.

We go through a full DMRG cycle and investigate its main steps for the spin-1/2 Heisenberg model and for the SU(2) Hubbard model. We also determine the MPS representation of the wavefunctions.

Operator decomposition using quantum numbers. Some basic matrix and tensor algebra.

Operator representations using non-Abelian symmetries. Some examples using DM-NRG.