

TDVP: Real-time evolution

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Here we will simulate the real-time evolution of quantum states in one-dimensional spin system, driven by time-independent Hamiltonian, by using **TDVP (time-dependent variational principle)** methods.

This exercise continue to study the same model XY spin chain as the previous **t-DMRG** tutorial.

Exercise 1: Complete TDVP_1site_Ex.m

There is a function `TDVP_1site_Ex.m` which is zipped together with this tutorial material. This function is designed to perform the real-time evolution of the MPS via the **one-site TDVP** method, and to measure the expectation values of local operators at each time step. **Complete the parts which are enclosed by the comments `TODO - Exercise 5`**. There are several remarks:

- The one-site TDVP algorithm for real-time evolution is quite similar to the one-site DMRG algorithm for ground-state search. So one may **recycle many lines from `DMRG/DMRG_1site.m`**! One can also follow the algorithm described in Appendix B of [[J. Haegeman, C. Lubich, I. Oseledets, B. Vandereycken, and F. Verstraete, Phys. Rev. B **94**, 165116 \(2016\)](#)] or [its arXiv version](#).
- Due to the similarity with the one-site DMRG, it requires the input of Hamiltonian as the matrix product operator (MPO). Again, one may copy-and-paste the lines from the tutorial T07a on the one-site DMRG.
- The `TDVP_1site_Ex.m` contains subfunctions `TDVP_1site_expHA` and `TDVP_1site_expHC` for the Lanczos method for local time evolution. Complete these subfunctions as well, by adapting from `DMRG/eigs_1site`.
- This is one-site update method, so the discarded weights are trivially zero. Of course, it does **not** mean that it does not suffer with entanglement growth with time. Indeed, it is worse, since one cannot dynamically change the bond dimension in response to the entanglement growth. This problem can be remedied by considering the two-site TDVP. The above mentioned paper by J. Haegeman *et al.* also describes how to implement the two-site TDVP method.
- Moreover, since it is one-site update method, **the initial MPS should have the bond dimension of `Nkeep`, and the TDVP function should not truncate the bond space.**

After completing the `TDVP_1site_Ex.m`, run the function for the XY spin chain as demonstrated above.