

Description of the code qtra.f

The purpose of this program is to solve the master equation of a given open quantum system. Up to now consists of two main subroutines that can be selected by using a number code. These systems correspond to the (modified) teleportation protocol (code number 1) and the quantum baker's map (code number 2). However the possibilities can be enlarged easily given the structure of the main program. In order to consider the effects of the environment, it implements a quantum trajectories' technique known as quantum montecarlo wave-function simulation. In brief, this procedure evaluates the probability for the system to "jump" through different noise operators that belong to a given noise channel and, considering these values against a random number, projects the wave function accordingly. This mechanism, repeated on several realizations of random numbers reproduces the results obtained by solving the master equation directly. As a useful measure of the environmental effects on the system we have chosen the widely known "fidelity", which is calculated as a function of the coupling parameter. In the teleportation case is the overlap between the original state to teleport and the one obtained after the protocol implementation. In the baker's map case is the overlap between the initial state to which the map is applied forth and backwards, and the corresponding final state. We have implemented 6 different models of quantum noise, that can be chosen by using a code list:

- 0 : threshold model for amplitude damping
- 1 : statistical model for amplitude damping
- 2 : Bit flip
- 3 : Both
- 4 : Phase flip
- 5 : Previous three together

As a quick example suitable for a first test we have made this program run for the baker's map implemented with 10 qubits and the phase flip noise. The results are provided in the file "fidelity.out", showing the coupling parameter

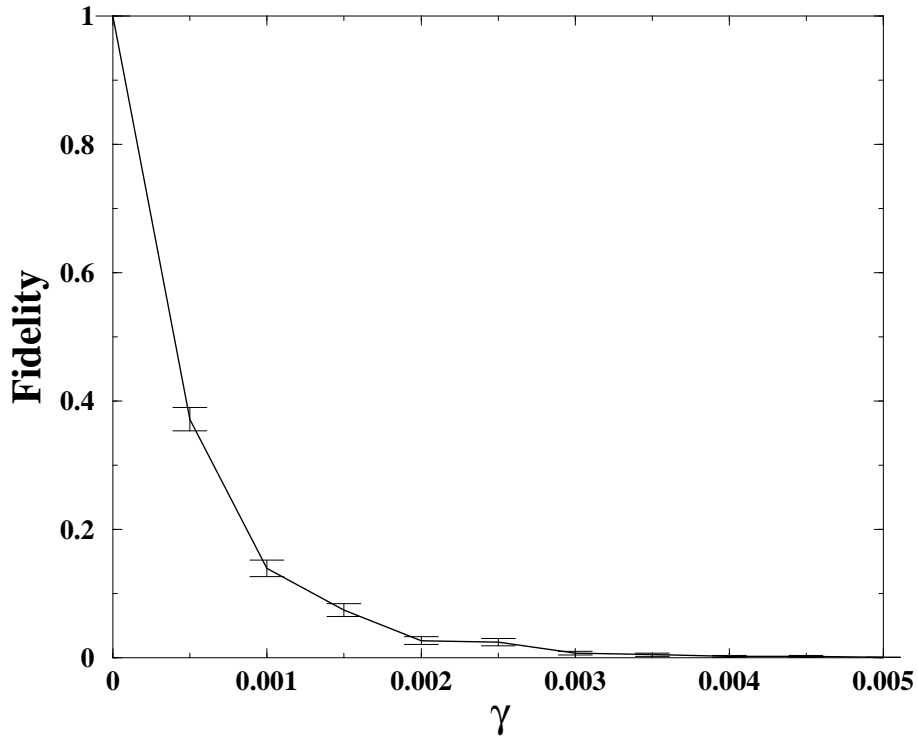


Figure 1: Fidelity of the baker's map as a function of the coupling parameter γ .

in the first column, the fidelity value in the second one, and the statistical error in the third one. Finally, this is parallel program that can be put into scalar form in a direct way, by commenting the parallel subroutines calls and modifying the instructions depending on the process number.

References

- [1] G.G. Carlo, G. Benenti and G. Casati, *Teleportation in a noisy environment: a quantum trajectories approach*, Phys. Rev. Lett. **91**, 257903 (2003).
- [2] G.G. Carlo, G. Benenti, G. Casati and C. Mejía-Monasterio, *Simulating noisy quantum protocols with quantum trajectories*, Phys. Rev. A **69**, 062317 (2004).