HPC simulation of a first quantum dynamical network —Internship—

Pablo Arrighi, Oguz Kaya

Abstract

Quantum theory allows for arbitrary superpositions of states, making bits into qubits and providing us with a natural source of parallelism. This parallelism is what powers the Quantum Computing advantage. In traditional Quantum Computing, the layout of the qubits however, is classical. They line on a line, a grid, or a graph, interacting with their nearest neighbour, but that graph is fixed once and for all. Many suspect, however, that this is not the end of the story. Just like we can have dynamical networks in classical computing, we ought to have quantum dynamical networks in Quantum Computing (Fig. 1). These networks may themselves evolve into superpositions, leading to quantum layouts of qubits. This is also in line with the idea that geometry is dynamical in gravity, and quantum dynamical in quantum gravity.

We recently gave a rigorous formalism for these quantum superpositions of networks [1], and so we are at the stage where we could begin to explore dynamics upon them, trying observe how these behave for the first time. Where to begin? It turns out that there exists a very simple, reversible network dynamics which exhibits a remarkable phenomena: a steady growth in spite of the reversibility [3, 2], evocative of the emergence of an arrow of time. The plan is to study a simple quantum variation of this HM model (Fig. 2).

Well actually, we have already tried. But the quantum parallelism of the model is precisely what makes it difficult to simulate due to exponential size. Clearly, we need an HPC approach to accelerate this simulation using multi-cores in a workstation to multiple nodes in a cluster, preferably using a task-based parallel programming model due to the computation having recursive nature with irregular problem sizes. The student will engage in writing this code, based on a previous Python version of the code and its author (Amélia Durbec). He will observe the growth behaviors of a first quantum dynamical network and seek to present these observations in a paper.

Desired qualifications:

- Experience and motivation in programming and code optimization, especially in C/C++.
- Taken at least one course on parallel programming (OpenMP, MPI, CUDA, vectorization)

References

[1] Pablo Arrighi, Marios Christodoulou, and Amélia Durbec. Quantum superpositions of graphs. *arXiv preprint arXiv:2010.13579*, 2020.

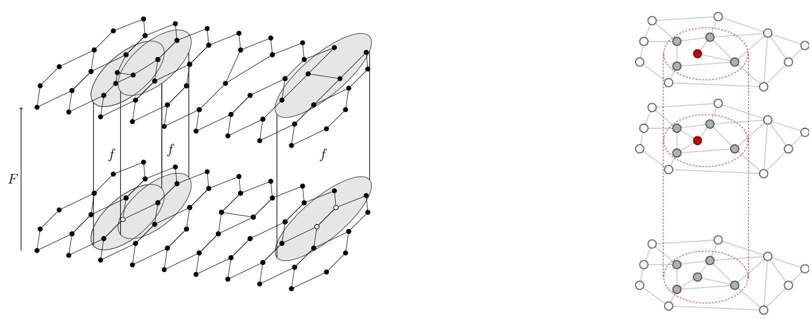

Figure 1: *A classical and a quantum network dynamics.* An entire networks evolves synchronously according to local rules.

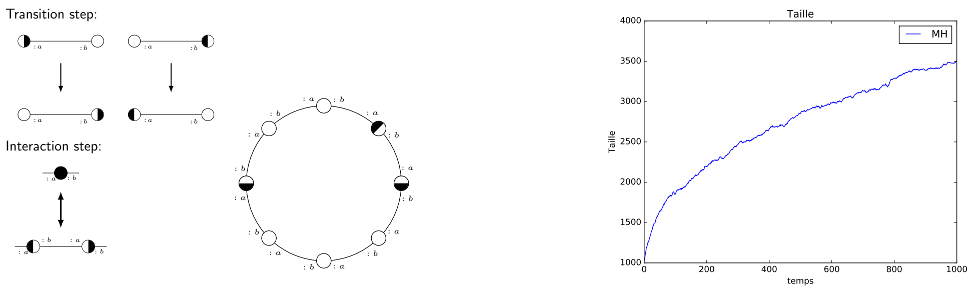

Figure 2: *The HM model and the typical size of the graphs as a function of the number of steps.*

[2] Pablo Arrighi, Nicolas Durbec, and Aurélien Emmanuel. Reversibility vs local creation/destruction. In *Proceedings of RC 2019, LLNCS*, volume 11497, pages 51–66. Springer, 2019.

[3] B. Hasslacher and D. A. Meyer. Modelling dynamical geometry with lattice gas automata. Expanded version of a talk presented at the Seventh International Conference on the Discrete Simulation of Fluids held at the University of Oxford, June 1998.