Fiche: ED MSTII, *allocations pour des étudiants extérieurs d'excellence*

Laboratoire: Laboratoire d'Informatique de Grenoble *(LIG)*

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Titre de thèse:

Quantum Cellular Automata for simulation and toy models

Acronyme:

QSIM

Résumé du projet de thèse:

The computationally efficient simulation of nano-scale quantum systems constitutes an challenging problem, whose solution would find relevant applications in many areas of Science: Biology (e.g. the understanding of the role played by the semi-quantum effects in energy transport during photosynthesis), Quantum Chemistry (synthesis of specific purpose molecules), Nanotechnologies to cite a few.

On the other hand, the implementation of approximate Quantum Computers is progressing, and it has become a matter of years before some prototypes are built. These first Quantum Computers will be very noisy due to interactions with the environment. In fact, they will be far too noisy to run any useful quantum algorithms. Yet, they may well be fit to run quantum simulations these nano-scale quantum systems... since nano-scale quantum systems are quite noisy themselves. Indeed, why wait for a perfect Quantum Computer, if the physical systems that we are trying to simulate is itself noisy? What does it mean for a noisy system to simulate another? Can such a simulation be exact?
This proposal seeks to tackle this problem at the theoretical level first, in the setting of models of computation, so that a precise meaning can eventually be given to the notion of an approximate Quantum Computer simulating a noisy quantum physical system.

The point of departure of this proposal, "Quantum Cellular Automata for simulation and toy models", is to approach this topic via two well-known theoretical models of computation - which have recently found direct application in physical systems. These models are the Quantum Walk (QW) and Quantum Cellular Automata (QCA) models; they constitute doubly strategic topics in this respect. First, they are privileged mathematical settings in which to encode the description of the actual physical system to be simulated. Secondly, they constitute a promising architecture for actual physical devices performing the simulation. Nowadays experimental physics groups have started to implement such QW and QCA system. Whilst these are still small and noisy, they are on their way to reach the size when their simulation power will exceed that of classical computer – provided that this notion of noisy simulation could be clarified.

One objective in this research proposal is to understand the absolute strengths and limits of QW and QCA for the sake of the simulation of physical systems governed by Partial Differential Equations (PDE's), including isotropic phenomena. Overcoming those limits will then take us beyond traditional QW and QCA models, to explore their extensions on different -possibly evolving- geometries, such as graph dynamics or interaction networks. Throughout the project, we will study

probabilistic extensions of the notion of simulation: axiomatizing noise models and understanding when they are equivalent, will place us in a position to tell whether a noisy quantum simulation of a noisy quantum system... is an exact one.

Documents de support:

Ci-dessous vous trouverez annexes des documents du candidat Marcelo Forets.