Résumé du projet de recherche (Langue 1)

Randomness has many beautiful applications across science and mathematics. On the one hand it provides powerful mathematical techniques, for example in Shannon’s proofs for channel capacity. On the other hand having access to random unitary transformations has recently found many applications not simply as a mathematical tool, but concretely in quantum information and beyond. For example in encrypting quantum data, quantum benchmarking, simulating thermalization and even black hole physics (recent work focuses on showing how black holes process information, the mathematical framework requires the use of t-designs and might just shed light on how particles behave inside Black holes). All of these applications enable us to better understand the behaviour of particles such as photons and electrons (or any particles from the particle zoo interacting in such a way as they can be entangled) unto which we can map these quantum properties. However two main obstacles remain in exploiting these ideas fully. Firstly, choosing a unitary genuinely at random is very difficult - it requires an exponential number of quantum gates and random bits. Secondly implementation of random circuits (the main approach to date for generating random ensembles of unitaries) is difficult - it requires reconfiguration of set ups depending on some random bit string. The first of these problems is treated by developing pseudo-random ensembles - choosing from finite sets of unitaries (often called “t-designs”) which can be done efficiently, yet mimic the desirable features of the genuinely random ensemble. A solution to the second problem has recently been addressed in the so-called measurement based approach [Turner, Markham, PRL 2016]. There, in a similar principle to measurement based computations, unitary evolution is achieved by preparing a large entangled state and performing local measurements. Unlike in computation however, rather than correcting the randomness of measurement outcomes, here it is put to use to generate useful ensembles. Indeed measurements replace the need for any classical randomness and hence the need for reconfiguration - the ensemble is generated by fixed measurements on a fixed entangled state. In this project the student will develop the recently introduced measurement based approach to sampling random unitaries and their applications [Turner, Markham PRL 2016]. We will search for new random ensembles, promising simple implementability and the possibility of use for applications. In particular the student will expand on this work in several directions, and exploit their use in cryptography, sensing and simulation. Furthermore, the student will work in collaboration with experimental groups to explore implementation in optics (photons and quantum photonics) and other set ups (such as ultracold fermi gases (fermions at low temperature) or bose Einstein condensates (Bosons at low temperatures )).

Informations complémentaires (Langue 1)

This work is done in the context of extensive international collaborations. Notably we expect to work alongside colleagues in Bristol, Germany and Singapore as well as Lebanon. These will be funded by international ANR grants and similar fundings.