I-QUINS: Spring semester workshop

February 11-15, 2019

Abstract

Program of the I-QUINS Spring workshop 19.

Program

- Tuesday March 12, Besançon. Seminars by I-QUINS PhD students and Post-doc. Amphi. Gagnepain
  - 14:00-14:45 *Quantum programs annotated by entanglement properties* (WP1) Henri de Boutray, FEMTO

    Abstract: Quantum programming languages are starting to be more and more popular and rich, yet, some important software engineering assets are still lacking in all the current languages. One of these skills is the ability to formally reason on various properties of a language. It will be the aim of my PhD. This talk in particular will focus on the proposition of a formal language to write quantum programs and specify them with formal properties.

    In particular, entanglement is believed to be a resource giving insights on the advantage of quantum computers over classical ones. For this reason, our language allows us to specify entanglement at any point of the program.
  - 15:00-15:45 *Detecting entanglement with Machine Learning* (WP1), Hamza Jaffali, FEMTO

    Abstract: Being able to recognize and caracterize entanglement for pure multipartite quantum state is a difficult task, but it is very important in many applications in the field of Quantum Information, such that Quantum Computation, Quantum Algorithms and Quantum Communication Protocols. In some special and limited cases, we are able to exactly determine the entanglement class of a quantum state. In this talk, we present several recent works using Machine Learning as an original technique to learn how to caracterize and recognize quantum entanglement of general or particular quantum states, trying to generalize several limited and existing mathematical techniques.
  - 15:45-16:15 Coffee break and discussions
  - 16:15-17:00 *Geometric Optimal Control and Applications to Spin Systems* (WP3) Quentin Ansel, UTINAM

    Abstract: Optimal control problems are usually solved using numerical algorithms but sometimes, an analytic approach is possible. By analogy with classical mechanics, the optimal control problem is translated into a variation calculus problem, and it is solved using Hamilton formalism. Hence, the problem of connecting two points of the configuration space with an unknown continuous control function while minimizing a cost is transformed into a problem of trajectory integration in a phase space. The goal of this talk is to introduce geometric optimal control, and to review two applications in quantum mechanics. The first one concerns the time

optimal control of selective/robust quantum pulses. We show that selective pulses are solutions of singular trajectories (of the Hamiltonian) while robust pulses are regular trajectories, which are entirely determined by two integers. The final solutions are given using simple analytic formulas and simple geometric interpretations are possible. The second application concerns recent results about the generation of entangled state in a spin system coupled to a cavity.

- Thursday March 14, Besançon, FEMTO-ST, Themis.
  - 9:30-12:00 Visit of the Optics departement (WP5) Jean-Marc Merolla.
  - 12:15-14:00 Lunch.
  - Seminars at LMB (Maths Dept of Univ. Besançon)
    * 14:00-15:00 *A number theory problem from quantum mechanics.* Ingemar Bengtsson, Stockholm Univ.
      Abstract: In quantum state tomography, and in classical signal processing, one is interested in finding maximal sets of equiangular lines, also known as SIC-POVMs, in complex vector spaces of arbitrary finite dimensions. It has proved remarkably difficult to do so, but the available evidence suggests that it is possible, and that the lines are spanned by vectors whose components, in a group theoretically preferred basis, belong to specific ray class fields with real quadratic fields as base fields. Optimistically, one can hope that this will lead to an explicit description of such number fields, and hence to a dent in Hilbert's 12th problem. I will describe an ongoing attempt to construct SIC-POVMs in an infinite sequence of dimensions.
    * 15:30-16:30 *Equivariance and application to entanglement detection.* Ivan Bardet, Cambridge Univ.
      Abstract: Deciding accurately whether a state is entangled is a hard problem. One reason is that it is hard to describe positive maps. However, there exist interesting approximate strategies, e.g. implementing an explicit version of the quantum de Finetti theorem via exchangeable states. Likewise, the same reasons, the similar problem of deciding whether a state is k-entangled is hard (the negation of k-entangle being k-separable, i.e. being a linear combination of pure states with at most k non-zero Schmidt coefficients). For this problem, the quantum de Finetti can not be directly applied and we have almost no strategy at hand. In this work with Benoit Collins and Gunjan Sapra, we revisit and formalize one key property of channels that we call (weak) equivariance, that makes it almost trivial to check k-postivity. Then, we study the channels having this property and unveil a close relation to the group representation theory of U(n) and PU(n). We also show that any k-entangled state can be detected by an equivariant k-positive map, which allows to construct effectively and systematically (k)-entanglement tests, and in principle sufficiently many to detect any k-entangled state.
  - 18:00-19:00 Visit of Besançon historitical center
  - 19:30 Dinner
- Friday March 15, Sévenans, UTBM, P418. Workshop on the geometry of entanglement
  - 9:30-10:00 Welcome coffee
  - 10:00-11:00 *Clifford groups and tensor products.* Ingemar Bengtsson
    Abstract: In composite dimensions there are two main variants of finite Heisenberg and Clifford groups. The one used in quantum computing is defined using a tensor product structure, the one used in signal processing — and in the SIC-POVM problem — has a more subtle

relation to tensor products. I focus on the latter, and some entanglement properties of SIC-POVMs that play a role when one tries to construct them in infinite sequences of dimensions. Things are especially subtle if the dimensions are even.

- 11:30-12:30 *Relating boundary entanglement to scattering data of the bulk in AdS_3/CFT_2.* Péter Lévay, Budapest Univ. of Technology and Economics

  Abstract: According to a recent idea bulk space-time is an emergent quantity coming from entanglement patterns of the boundary. By studying the space of geodesics in AdS_3, and quantizing a parametrized family of geodesic motion we show that scattering data is related to boundary entanglement of the CFT_2 vaccum. For the parametrized family of geodesics we calculate the Berry curvature living on the space of geomdesics. As a result we recover the Crofton form with a quantum coefficient related to the scattering energy. We argue that, by applying results coming from Algebraic Scattering Theory, this idea can be generalized for more general states and possibly for the general AdS_{n+1}/CFT_n correspondence.

- 12:45-14:00 Lunch

- 14:30-15:30 *Geometry of the dynamics of an entangled quantum system.* David Viennot, UTINAM

  Abstract: Since the pioneer works of Barry Simons in 1983, the geometric representation of quantum dynamics is well known to be the holonomy into a principal bundle where the base space is the manifold of pure (normalized) quantum states (without phase). This representation is intimetely related to the concept of geometric phase. An interesting question is the generalisation of this representation to the dynamics of quantum mixed states. In this presentation we will focus on mixed states resulting from the entanglement of a quantum system with another one by partial trace on the state space of this last one. Applications to quantum control hampered by entanglement and to decoherence phenomenons will be presented.

- 16:00-17:00 *Geometry of symmetric states and binary forms.* Frédéric Holweck, ICB

  Abstract: Entanglement classification of pure multipartite quantum systems is a difficult problem when the number of partite increases. For 5 qubits, one knows that an exhaustive classification of the SLOCC orbits is out of reach. In this talk, I will focus on the special case of symmetric states. This is a case of interest for quantum information as many quantum protocols involve symmetric states like $|GHZ\rangle$, $|W\rangle$ or the Dicke states. This case is also interesting for quantum physics in general as it is known that spin coherent states can be written as symmetric states. In this talk, I'll deal with two representations of symmetric states: the Majorana's representation well-known to physicists and the geometry of the Veronese curve well-known to algebraic geometers. It turns out that the geometry of both those representations are connected to an old problem of invariant theory: the classification of binary forms.

- 19h30 Dinner