INSTITUT NEEL Grenoble
Available PhD Thesis Grant

Orbital Angular Momentum N-photon states for socially optimal decision making

Description of the scientific project and its interest. Exploring new strategies for decision making is a major need in view of scaling up the capability to manage extended numbers of "bandits" (players in the theory game language), but also to deal with complex choices with an arbitrary number of outcomes. At the same time, maintaining the ability to remotely control the type of interactions among players is the cornerstone of this project. To fulfill these global challenges, all resources offered by the quantum nature of photons have to be exploited: coherence (allowing correlated responses among players), quantum superposition (providing unique properties driving the player choices), and all degrees of freedom associated with massless particles (scaling the available phase space). In this view, new aspects will be introduced in decision-making strategies: (i) photons multiplets will be generated for emulating larger player assemblies (ii) orbital angular momenta (OAM) will widen the number of degrees of freedom (available choices) compared to polarization-based strategies, (iii) the level of discernibility will be exploited to control the coherence of the player choices and (iv) the full spectrum between factorizable states to quantum-entangled ones will select the type of rules introduced among players. For this proposal, we aim to conduct research on parallel exploration-exploitation optimization on all theoretical, numerical, and experimental fronts, expanding previous works to more "arms" (choices in the game theory language), more realistic situations and with quantitative comparison with existing conventional algorithms. Based on the fundamental quantum nature of light, this work is foreseen to bring significant advances in various domains such as resource sharing, reinforcement learning, and parallel quantum processing.

Objectives. First, based on game theory, we want to establish the protocols required for N players (photons) having M possible choices (angular momenta) within a wide range of social rule ranging from full individualism (discernible photons) to team working (indiscernible particles) with specific interactions schemes (from factorizable to entangled quantum states). As clearly indicated within the parentheses, this will require working in parallel on a theoretical ground to exploit all known quantum properties of photons. Second, our goal is to provide proof-of-concept by building experimental setups allowing for manipulation of all photon degrees of freedom, which implies building multiple photon sources (not only single or photon-pair sources but configurations providing the emission of N photons with a given degree of entanglement), manipulating OAM and discernibility, and lastly designing detection apparatuses for translating the quantum properties of the prepared photon states into decisions. Finally, in order to validate the new quantum decision strategies proposed here, we will compare both theoretical and experimental results to existing conventional algorithms to demonstrate their superiority.

Added-value of the international cooperation. This work will be funded through the joint CNRS-UTokyo program, for which a PhD thesis grant is provided on both sides with financial support for travelling expenses. The team in CNRS Grenoble is specialist in optics and photonics experimental research, with expertise ranging from nonlinear optics to plasmonics, from near-field optics to quantum optics, with promising local collaboration perspectives thanks to the cutting-edge related research activity in Neel Institute. Its expertise in game theory and related artificial intelligence topics is new, limiting its ability to apply in full autonomy its

research to this very active domain. On the other hand, the team in UTokyo has a renowned expertise in developing photonic systems devoted to applications including decision making, generative adversarial network, or Q-learning. This project is the perfect opportunity to reinforce the existing 8-year-old collaboration (some 10 common publications) between these two very complementary teams, to broaden the spectrum of applications on the CNRS Grenoble side and contribute to the development of the research activity on the UTokyo side.

Formation / Competences. The successful candidate is expected to have (or to earn soon) a Master or equivalent degree in physics and to be interested in both theoretical and experimental aspects of quantum optics research. He or she will apply for a PhD scholarship to work under the supervision of Guillaume Bachelier at Institut Néel in Grenoble, France. However, he or she will be strongly involved in an international collaboration and will travel to Tokyo at least once a year for several weeks in the team of Prof. Makoto Naruse, who has a wide collaborative network through Japan and beyond, and who will supervise the PhD student working on this project at UTokyo.

Contact. Interested candidates must apply using this website before the end of June: https://emploi.cnrs.fr/Offres/Doctorant/UPR2940-ELOBER-045/Default.aspx