Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA18232

Grantee name: Dr. Michael Mc Gettrick

Details of the STSM

Title: Interacting dynamics of quantum agents on graphs

Start and end date: 26/02/2022 to 11/03/2022

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

(max. 500 words)

In this STSM, Dr. Mc Gettrick (National University of Ireland Galway) visited the group of Dr. Gomez (Universitat Rovira I Vergili, Tarragona, Spain) for two weeks to work on dynamics of interacting quantum agents on graphs. As part of the visit, Dr. Mc Gettrick gave a seminar on his directions of research to the group of Dr. Gomez. The work carried out is in a completely new direction of research in its "quantum" aspect. Up to now many researchers have worked on interacting agents on graphs (involving effectively iterated games with strategy updates, where the graph comes in to play in deciding both "who plays who", and in dictating the strategy update rules). Adding in quantum entanglement to the games being played changes the resulting payoffs.

We considered mainly in the discussions 2-person 2-choice cooperative games of incomplete information, such as the CHSH game. For the issue of entanglement, bipartite entanglement is well understood (less so tripartite or multipartite entanglement), so we considered supplying maximally entangled pairs of qubits along various edges of the graph (various pairs of players in the game). The question then becomes, if one has fewer maximally-entangled-pairs to provide than there are edges on the graph, which edges do we pick (for a particular graph) to optimize the average payoffs for all players? Simple graphs were considered, such as the straight-line graph, cycle-graph, star-graph. Initial observations were made that the graph topology affects the assignment of maximally entangled

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

pairs (for example, for assignment of a single pair, all edges are equivalent for the star or cycle graph, but not for the straight-line graph). Further discussions followed on assigning tripartite entangled states (such as the inequivalent W or GHZ states) to three players. This proved more problematic for two reasons: (1) It is not obvious how the graph structure plays a role in selection of groups of 3-players, unless we consider triangles in the graph, (2) Even after assignment of tripartite entangled states, the calculation of the optimal payoff of the game is not easy. Because of these difficulties, we spent most of the time analyzing the bipartite case.

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

(max. 500 words)

The collaboration went well, considering the parties involved had not worked together previously. The STSM did achieve its goal of initiating a new collaboration, in a new research area, involving quite a few different fundamental scientific disciplines (physics, mathematics, computer science). We have analyzed successfully the scenarios involving the assignment of maximally entangled bipartite quantum states to quantum agents. A very interesting result is, the assignment of such states to edges of the graph results (in the case where each player may have access to more than one qubit) in changing the graph, effectively adding a new node. In many cases we analyzed, this change can break a connected graph into disconnected parts. We plan to continue this work to see, for specific graphs where the number of entangled pairs is less than the number of edges, what is the optimal assignment.

While analyzing just bipartite entanglement is one aspect of the work, we plan to work towards a publication involving more general assignment of multipartite entanglement, for certain graphs. We view this work as contributing centrally to the Action: Such interacting quantum agents on a graph are in fact one model of a dynamical system on a network, that can be implemented in practice (since it obeys the rules of quantum mechanics). Gomez and Mc Gettrick have set up a shared workspace in SLACK to communicate regularly on these ideas, as well as writing up calculations in OVERLEAF as we progress.