Quantum Walking over a discrete sphere

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Place: Laboratoire d'Informatique et Systeme (LIS), Natural Computing team (CaNa). Scientific environment: The CaNa research group (Pablo Arrighi, Giuseppe Di Molfetta, Kevin Perrot, Enrico Porreca, Sylvain Sene) seeks to capture at the formal level some of the fundamental paradigms of theoretical physics and biology, via the models and approaches of theoretical computer science and discrete mathematics. The group is located in Luminy, Marseille, France, and benefits from a rich scientific environment with the Cellular Automata experts of I2M (Pierre Guillon, Guillaume Theyssier) and the physicists from CPT (Alberto Verga, Thomas Krajewski, Rovelli group).

Theme and goals A Quantum Walk (QW) is essentially an operator driving the evolution of a single particle on the lattice, through local unitaries. It can be seen as the single particle sector of a Quantum Cellular Automata. Similarly to Classical Random Walk, QW are used to model and to simulate a wide range of phenomena, from biology to physics, and they have been largely employed in algorithmic. Recently QW have been defined on static and dynamical simplicial complexes and were further generalized to be used in quantum search algorithms. All these results pave the way to QW and further QWs models as platforms for simulation on trivalent graphs [1]. There are numerous motivations for this departure from the squared grid. One is the hot topic of quantum propagation on fullerene-like materials [3], and within nanostructure in general. Quantum transport within such materials may be the physical phenomena that we wish to model by QW. Yet another motivation for exploring

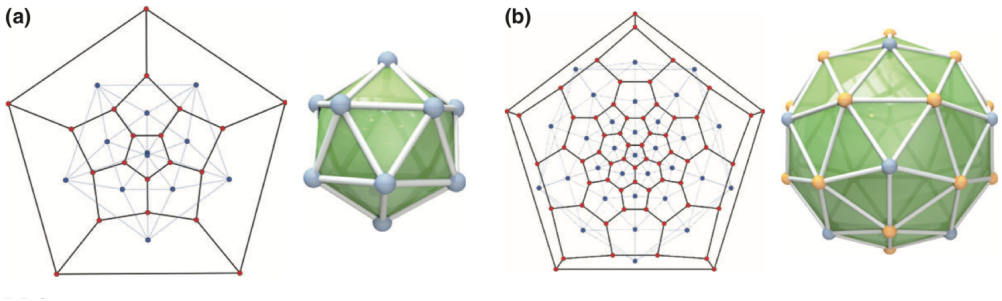

FIG. 1: Planar embeddings of fullerene graph and dual (blue color and dotted lines for the dual representation), and 3D embeddings of the duals: (a) C20-Ih, for which the dual is the icosahedron; (b) C60-Ih, for which the dual is the pentakis-dodecahedron [3].

QW over simplicial complexes is its application to non flat-geometry. It is well know that, e.g., a sphere can be discretised by triangulation and a truly discrete analogous of curvature arises. This problem is reminiscent of the question of matter propagation in triangulated spacetime[2].

During this internship we will define a QW over regular triangular mesh of the sphere and we will study the propagation of the walker over the dual graph as in Fig. 1. The main aim is to relate the propagation of the walker to the discrete curvature.

Prerequisite: Strong programming skills, basic knowledge of linear algebra, knowledges in differential geometry, quantum information or quantum mechanics is atout but not necessary.
The internship will funded as legally required.

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[1] Pablo Arrighi, Giuseppe Di Molfetta, Iván Márquez-Martín, and Armando Pérez. The dirac equation as a quantum walk over the honeycomb and triangular lattices. *arXiv preprint arXiv:1803.01015*, 2018.

[2] Carlo Rovelli. Simple model for quantum general relativity from loop quantum gravity. In *Journal of Physics: Conference Series*, volume 314, page 012006. IOP Publishing, 2011.

[3] Peter Schwerdtfeger, Lukas N Wirz, and James Avery. The topology of fullerenes. *Wiley Interdisciplinary Reviews: Computational Molecular Science*, 5(1):96–145, 2015.