# Quantum Error Correction in Loop Quantum Gravity

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**Abstract.** Research in AdS/CFT has shown that quantum error correction must play an important role in the emergence of macroscopic spacetime from entanglement between some, as yet undetermined, fundamental, "pre-geometric" degrees of freedom. One approach to quantum gravity is loop quantum gravity (LQG) in which these pre-geometric degrees of freedom take the form of spin network states. I show that by considering the action of diffeomorphisms on spin-networks one arrives at the Yang-Baxter equation. Solutions of this equation correspond to quantum circuits which can generate qutrit states (of the form |000> + |111>) which are the fundamental ingredient of certain well known quantum error correction schemes. This provides support for spin networks as a physically plausible candidate for the "atoms" of spacetime and also suggests avenues for connecting LQG with the AdS/CFT conjecture. (based on https://arxiv.org/abs/1912.11725)

**Keywords**: loop quantum gravity, quantum error correction, ads-cft, yang-baxter equation

Previous works (by Almiehri, Dong, Harlow, Pastakawski, Preskill, Yoshida and others) have established that quantum error correction plays an important role in understanding how the bulk degrees of freedom of an Anti-deSitter spacetime are encoded in the degrees of freedom of the boundary Conformal Field Theory. In previous work [1] I have argued that the Bilson-Thompson model [2, 3] of elementary particles allows us to view elementary particles as gates for universal quantum computation. In the present work I show that the Bilson-Thompson model, where elementary particles are represented by elements of the framed braid group on three strands, provides an explicit model for the generation of qutrit (three-qubit) states which are the ingredients of Shor's quantum error correcting code. This allows, for the first time, to connect in a concrete manner the proposals of Almheiri, Pastawski, Preskill and others regarding the role of quantum error correction in quantum gravity, to a viable model of elementary particles. Loop Quantum Gravity (LQG), the theory of quantum gravity in which such topological excitations exist, can thus serve as the glue which can connect AdS/CFT based approaches to quantum gravity to the well understood physics of the Standard Model.

## I Observations

In this work we have made the following observations. First, in order to consider the full state space of loop quantum gravity, knotting and braiding of spin-network edges needs to be taken in account. Second, the action of the operator version of small diffeomorphisms is given by the Yang-Baxter equation whose solutions yield a two qubit unitary gate which is universal for quantum computation. And, finally, the inclusion of topological degrees of freedom allows us to generate states which are essential ingredients in quantum error correcting codes.

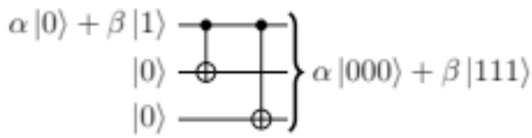


**Figure 1** Quantum circuit for generating GHZ states

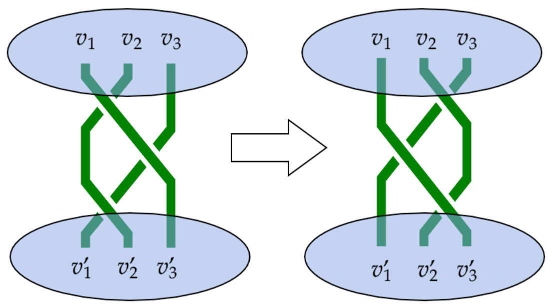


**Figure 2** Reidemeister type IV moves acting on a set of three spin network edges.

It is also interesting to note that the braid configurations shown in Figure 3 are identical to those in the groundbreaking work by Sundance Bilson-Thompson [4, 2] wherein he identified these states with leptons belonging to the first generation of the Standard Model of elementary particles.

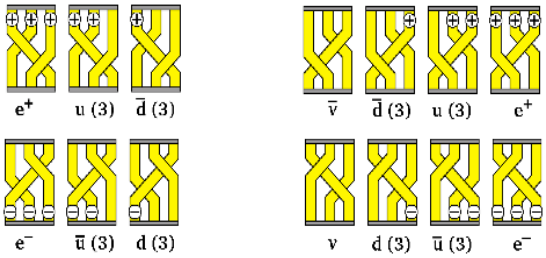


**Figure 3** Bilson-Thomspson model: first generation of the standard model represented in terms of elements of the three strand braid group.

**References**

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