Research Proposal

1 Title

The application of theoretical quantum gravity models to the development of qubit architectures.

2 Introduction

There are many approaches being studied in Quantum Gravity, the two most prominent being string theory and loop quantum gravity. The study of geometric models of a quantum nature that arise here can be used to develop frameworks which model qubits for applications in various areas of quantum technology, such as quantum computing. Specifically, the ideas of holography and geometrical networks along with the increased understanding of black hole entropy has revealed the quantum nature of information and lead to advancements in quantum information theory, which, in turn, has lead to advancements in various fields in quantum technology such as computation and communication.

3 Research Objective

- Find a meaningful way to apply geometrical approaches in QG to the development of qubit architectures.

3.1 Sub-Objectives

- Study the use of holography in various related fields and all its possible applications to understand its use in studying black hole thermodynamics with a special focus on the ADS/CFT correspondence and its use in various QG frameworks
- Study the use of geometric models of quantum spacetime to model qubit networks and quantum phenomena such as entanglement and decoherence
- Apply such models of QG to be able to develop quantum logic in a rigorous manner which can be used to perform algorithms and related tasks in a more efficient manner compared to classical methods.

4 Background

I pursued a BS in Physics from UCSD with a minor in mathematics, focusing especially on quantum mechanics and general relativity. I was primarily focused on two research pathways: a study of quantum fluctuations in the early universe, and a general study on various topics related to general relativity, such as the role of torsion in different formulations of the theory and the implications of the singularity theorems. I wrote a paper on the singularity theorems, which gives an overview and also future implications on this topic. I have also independently, but under the guidance of a professor, studied the role of gauge theories in particle physics and attempted to give a geometric description of these gauge

theories, with an implication about a possible theory in quantum gravity. I have a website where I post these findings, along with other related material, www.qgspinor.com.

5 Methodology/Proposed Research Direction

- Understand the use of major concepts in quantum gravity, such as CFT, in formulating consistent models of spacetime and black holes. Especially focus on entropy and the role of quantum information.
- Study the role of noise in negatively affecting both the ability to scale and the ability to accomplish tasks in a more efficient manner than current classical methods.
- Apply various theoretical models from quantum gravity to model qubit behavior, such as entanglement, superposition, and decoherence.
- Analyze if any of them are particularly appealing in providing solutions to current challenges while also being theoretically consistent; see how such architectures improve upon currently existing ones.
- Particularly focus on the architecture of topological qubits, which have a natural geometric interpretation akin to the structure of QG models and are directly related to ideas in QG such as gauge theories.

6 Fit With Program

NUS is an ideal university to conduct this research. Learning under professors such as Kuldip Singh who focus on the geometrical aspects in quantum gravity related areas would provide invaluable experience in building consistent theories to apply in quantum technology. Also, studying under others who specialize in quantum effects such as Dagomir Kaszlikowski would provide guidance on how to transform these models into architectures which can be used in areas such as quantum computing. Centers such as the CQT which is a leader in quantum technology development in the world would expose me to the most recent developments and research directions in this field. It would also give me the opportunity to collaborate with the professors and researchers who are working here. Also, my variety of abilities in formulating theoretical approaches, having mathematical maturity, and being able to program in various languages, along with my interest in technology development, allows me to contribute meaningfully while also giving me the versatility needed to excel in different research contexts.

7 Future Goals

There will be many different opportunities upon the completion of this research since I'm open to exploring many related fields and directions. My complementary goal is to use the insights I gain from this research towards the development of practical quantum architecture, with a focus on designing quantum computers for real-world applications. Completing this research would give me the necessary skills and experience to make this goal a reality.