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Project Title: Design and Implementation of a FPGA-based Quantum Circuit Simulator

Project abstract:

We plan to explore FPGAs as well as Quantum Computing, our objective being to implement quantum gates using VHDL.
The aim of this project is to develop a quantum circuit simulator using FPGA, which will involve designing a digital circuit for the Hadamard gate (fundamental quantum gate) and then implementing the gate on the FPGA using VHDL.
Motivation: Quantum Computing is a rapidly advancing field that promises to revolutionize the way we solve complex problems. However, the development of quantum hardware remains a challenging task due to the inherent fragility of quantum systems. As a result, quantum simulators are an important tool for testing and optimizing quantum algorithms. While traditional CPU-based simulators are commonly used, they are often limited by the computational power of the hardware they run on. By contrast, FPGA-based simulators have the potential to offer significant improvements in speed and efficiency. Additionally, the scalability of FPGA-based quantum circuit simulators means that they have the potential to simulate larger and more complex quantum algorithms. Hence, a FPGA-based quantum circuit simulator would not only provide us with additional knowledge of both quantum computing and digital electronics but they would also provide considerably larger efficiency compared to traditional CPU-based simulators, making them perfect for this project.

Project proposal Detail:

Planned division of work between the two group members: Both team members have limited prior experience with VHDL code and thus this project would entail a combined effort with both members. We plan to work collaboratively and utilize each other's strengths. Simran has a background in quantum computing while Ananya is pursuing a CS minor, which would allow us to approach the project from 2 different yet complementary perspectives.
As such, we expect our project to primarily consist of an effort from both sides involving frequent communication and a joint learning process

Project work milestones:

Week 1: Review the literature on quantum computing and digital circuits for quantum gates, implementing basic classical gates using VHDL, design a digital circuit for the Hadamard gate using FPGA components, attempt to write VHDL code to implement the digital circuit for the Hadamard gate

Week 2: Continue working on the VHDL code to implement Hadamard gate, Load the VHDL code onto the FPGA and verify(measurements) its functionality using simulations, attempt to implement other quantum gates

Week 3: Develop a quantum circuit simulator using the FPGA-based Hadamard gate and other quantum gates implemented in Week-2, additionally add features such as measuring the system in the non-computational basis, evaluating the performance of the FPGA-based simulator

Backup plan:

The scaled-down project could include:

- Focusing solely on the design and implementation of the Hadamard gate using FPGA, without attempting to implement other quantum gates
- Skipping the development of a quantum circuit simulator using the FPGA-based Hadamard and other gates, instead focusing on the verification and evaluation of the Hadamard gate circuit itself
- Reducing the number of simulations/bits and measurements performed to verify the functionality of the Hadamard gate

By scaling down the project idea, it would be possible to deliver a finished project within the timeframe and also meet the project's objectives.