QuantEx: A Tensor Network Simulator for Quantum Circuits

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I. Abstract

In this poster we will showcase the QuantEx project: one of the 10 independent software projects constituting work package 8 of PRACE-6IP. The QuantEx project aims to deliver a novel open source quantum circuit simulator, based on tensor network methods, to the scientific community which is capable of scaling on pre-Exascale and Exascale compute platforms.

The ability to simulate quantum circuits is essential for the design and development of quantum computing hardware and algorithms. With the recent emergence of Noisy Intermediate Scale Quantum (NISQ) devices, it has become intractable to simulate devices of this size using direct evolution of the full quantum wave-function, even on the largest supercomputers [1]. To simulate a quantum circuit with a large number of qubits, the circuit can be represented as a network of tensors, enabling output probability amplitudes to be calculated by contracting the network [2], [3]. A simulation of a large quantum circuit involves computing a large number of probability amplitudes and contracting a tensor network representing the quantum circuit consists of a large number of tensor contraction operations which can be mapped onto matrix multiplications. Hence, HPC resources are required to perform the very many tensor operations constituting the simulation. This approach has achieved state of the art performance when simulating Random Quantum Circuits (RQC) as part of the recent quantum advantage experiments [1].

The developed simulator consists of several special purpose software packages aiming to address different issues that arise in tensor network simulations. These are QXTools, QXTns, QXGraphDecompositions and QXContexts, and can be found on github under the JuliaQX organisation[1]. The popular scientific computing language Julia [4] is used as the primary language, because of its flexible type system, the ability to wrap components in other languages while also providing native performance and native support for GPGPU programming.

Implementation details of the simulator are given in [5] along with initial testing results. The software was successfully tested on Intel and AMD CPUs and on NVIDIA GPUs and future work includes expanding the supported hardware to include AMD GPUs and Intel GPUs. Profiling and optimisation work is currently on going and scaling results on a tier-0 system are expected by the end of 2021. We hope to showcase these results in this poster.

Future work on QuantEx the project includes further optimising circuit simulations and testing the software on the forthcoming european pre-Exascale and Exascale machines [6], [7]. Optimizing simulations may be achieved via improved network contraction planning capabilities and better bitstring sampling methods. Furthermore, efforts are ongoing to identify suitable opportunities to integrate the developed tools into commonly used quantum circuit simulation frameworks. One particular direction the QuantEx team is exploring is the possibility of integrating quantex as a backend for the popular Yao.jl [2] framework. The Julia package YaoQX.jl [3] was developed with the hope of enabling Yao.jl users to take advantage of distributed systems and pre-Exascale and Exascale HPC clusters to simulate quantum circuits.

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[2]https://github.com/QuantumBFS/Yao.jl

[3]github.com/JuliaQX/YaoQX.jl