WKS05 — Towards Error Correction within Modular Quantum Computing Architectures

Sun, Sep 15, 2024. Montréal, Québec, Canada

Abstract

Recent advancements in the improvement of quantum processors' reliability and the increase in the number of qubits that can be controlled stably have enabled the development of the first practical implementations of quantum error correction (QEC) codes with a finite encoding rate and optimal scaling of the code distance. However, to keep reducing the logical error rates by several orders of magnitude, a much larger number of protected qubits is imperative, which requires substantially scaling up current quantum computing platforms. A promising bet on architectural scalability is the modular multicore approach, which requires a tight interplay between quantum computing cores and quantum and classical communication links.

Accordingly, we aim in this workshop to foster the interaction of these two emerging subdisciplines and related communities. For this to materialize, multicore architects must deeply understand the requisites of QEC codes, while code designers must be aware of the practical constraints and possibilities of multicore platforms and frameworks, including both communication and computation full-stacks. This symbiotic relationship pursues a virtuous cycle, facilitating ongoing advancements in qubit count and device reliability.

To this purpose, in this workshop, we bring in experts from different communities to address common challenges and cross-dependencies between areas, namely (a) modular multicore architecture, (b) quantum error correction, (c) decoding design, (d) real-time quantum control, (e) communication technologies, and (f) compilation of large-scale quantum algorithms, all of them addressed mainly from an architectural design and implementation perspective with a multidisciplinary approach.

Keywords: Modular architectures, quantum error correction codes, quantum communication, real-time quantum control, large-scale quantum algorithms, quantum error correction decoding.

Target Audience

The target audience will cover several communities, areas, and backgrounds from both Industry and Academia, such as full-stack quantum computing architects/engineers, quantum coding theorists, quantum device and communication link technologies, experts in quantum frameworks and compilation tools, quantum software engineers, digital circuits and VLSI designers of control and real-time decoders, physicists, whose main interest will be to learn both needs and solutions for the next generations of fault-tolerant large-scale quantum computers. Additionally, the workshop aims to reach out to end-users of

quantum computers who are interested in the mid-term evolution of computing systems in reliability and scalability.

The workshop will also target students and young researchers who are interested in the topic as well as other professionals with expertise in classical computing areas with an interest to contribute to the quantum computing field.

Workshop Program

Session 1 - 10:00-11:30 (EDT) Fault-tolerance-aware modular quantum system architecting

- Eleanor Rieffel (NASA Ames Research Center)
- Henry Semenenko (Quantinuum): "Quantum Error Correction and Scaling with Trapped-Ions"
- Madelyn Cain (Harvard University): "Algorithmic Fault Tolerance for Fast Quantum Computing"
- Teague Tomesh (Infleqtion): "A full-stack approach to modular and heterogenous quantum computer architecture design"

Session 2 - 12:00-13:30 (EDT) Quantum error correction, towards modular quantum architecture

- Lucas Berent (Technical University of Munich): "Quantum LDPC codes for modular architectures and efficient decoding"
- Noah Shutty (Google Quantum AI): "Efficient near-optimal decoding through ensembling"
- Andrew W. Cross (IBM T. J. Watson Research Center): "Logical gates on LDPC codes"
- Valentin Savin (Université Grenobles Alpes, CEA-Léti): "Fault-tolerant preparation of quantum polar codes"

Session 3 - 13:30-14:30 (EDT) Panel discussion with all speakers: "In pursuit of scalable modular fault-tolerance"