WKS04 — Practical Quantum Error Correction and Fault-tolerant Quantum Computing: a Full-stack Approach

Sun, Sep 17, 2023. Bellevue, Washington

Abstract

The implementation of a fault-tolerant (FT) quantum computer is crucial to satisfy the large-scale requirements of quantum algorithms that will release the potential of quantum computing in a wider range of areas. Despite the huge advances performed in NISQ devices for the different layers of the full-stack, in fields like quantum error correction coding and co-processor designs for real-time decoding, most of the proposals show a large gap between the results obtained with theoretical simulations and the implementation in real devices or do not address crucial issues such as scalability. For instance, key questions related to quantum hardware resources and architecture for protecting physical qubits in large-scale quantum devices for several code families and technologies are still an open problem. In addition, although hardware-agnostic proposals will allow more portable solutions between devices and architectures, realistic noise models should be defined to quantize the impact of quantum error correction and mitigation techniques under different scenarios. In the same way, holistic compilation techniques to deal with a variety of error sources and support FT quantum operations have to be explored. Finally, the implementation of real-time error decoding co-processors that meet timing and power constraints for several quantum technologies should be considered, making a deeper analysis of the environmental conditions in which these co-processors will be running as well as the interfaces employed to communicate with the quantum device.

The aim of this workshop is to bring experts representing different FT and quantum error correction (QEC) efforts that include: (a) quantum hardware and architecture design for error corrected large-scale quantum devices, (b) implementation and evaluation of QEC on real devices, (c) compilation of FT quantum circuits, error-aware and mitigation techniques and realistic noise models, and (d) new quantum code constructions and decoding aspects, with emphasis on real-time quantum error correction decoders.

Keywords: Fault-tolerant quantum computing, Error-aware compilation techniques, Quantum processor resources, Noise models, Quantum error correction (QEC), QEC codes, Real-time decoders for QEC

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, physicists, quantum coding theorists, experts in quantum frameworks and compilation tools, quantum software engineers, circuits and VLSI designers, whose main interest will be to learn both needs and solutions for the next generations of fault-tolerant large-scale quantum computers from a full-stack approach as active players in future designs. On the other hand, the workshop also targets final users of quantum computers, who may be interested in the state-of-the-art of nowadays devices and in how to scale up and make more reliable quantum computing systems.

The workshop will also target students and young researchers that are interested in the topic as well as other professionals with expertise in classical problems but with an interest to contribute in the quantum field, with the aim of making faster progress in the design of fault-tolerant solutions.

Workshop Program

Session 1 - 10:00-11:30 (PDT) Quantum hardware/architectures and compilation techniques for fault-tolerant quantum computing

- Ken Brown (Duke University): "What is a fault?: Advantages of hardware-specific fault-tolerant constructions"
- Daniel Litinski (PsiQuantum): "An architecture for efficient fault-tolerant quantum computers with limited non-local connections"
- William Zeng (Unitary Fund): "Error mitigating compilation: the gradual onramp towards fault-tolerance"
- Josh Mutus (Rigetti): "Algorithm-driven fault-tolerant architectures based on superconducting qubits"

Session 2 - 13:00-14:30 (PDT) Quantum error correction, code constructions and decoding aspects for real-time co-processors

- Dave Bacon (Google Quantum AI): "Realistic Quantum Error Correction In Space and Time"
- Francesco Battistel (Qblox): "Advanced quantum computing and error correction in a highly distributed quantum control stack"
- Nicolas Delfosse (Microsoft Quantum): "Spacetime codes of Clifford circuits"
- Nithin Raveendran, Asit Kumar Pradhan (University of Arizona): "Efficient decoder design for QLDPC codes using neural network"

Session 3 - 15:00-16:30 (PDT) Panel discussion

(*) Times in Paci ic Time (PDT)