23/05/2024

TQCI Seminar

2nd TQCI International Seminar on Benchmarks for Quantum Computers.

4-5 June 2024 – REIMS from June 4, 1:00 pm to June 5, 5:00 pm

BACQ Consortium – Delivering an application-oriented benchmark suite for objective multi-criteria evaluation of quantum computing performance, a key to industrial uses

With the support of the national program on measurements, standards, and evaluation of quantum technologies MetriQs-France, a part of the French national quantum strategy, the BACQ project (Application-oriented Benchmarks for Quantum Computing) is dedicated to application-oriented benchmarks for quantum computing. The consortium gathering THALES, EVIDEN, an Atos business, CEA, CNRS, TERATEC, and LNE aims at establishing performance evaluation criteria of reference, meaningful for industry users. Partners will present progress of BACQ project.

EVIDEN, QUANDELA, TNO, PASQAL, IQM- Experimentation Campaign on QPUs Using Q-Score Metric

In the framework of the BACQ project, a joint effort has been made by the collaboration and several partners to carry out an initial measurement campaign on the existing QPUs using the Q-score metric.

In this session, following a brief introduction by Eviden, the partners from Quandela, TNO, Pasqal, and IQM will present their implementations of the Q-score and discuss their results.

Koen MESMAN, TUDELFT/TNO- QuAS: Quantum Application Score for benchmarking the utility of quantum computers

Benchmarking quantum computers helps to quantify them and bring the technology to the market. Various application-level metrics exist to benchmark a quantum device at an application level. This work presents a revised holistic scoring method called the Quantum Application Score (QuAS) incorporating strong points of previous metrics, such as QPack and the Q-score. We discuss how to integrate both, and thereby obtain an application-level metric that better quantifies the practical utility of quantum computers. We evaluate the new metric on different hardware platforms such as D-Wave and IBM as well as quantum simulators of Quantum Inspire and Rigetti.

Hari KROVI, RIVERLANE - Benchmark problems in plasma physics and computational fluid dynamics and quantum approaches to solve them

We give an overview of some important benchmark problems in plasma physics and computational fluid dynamics and discuss their utility. Specifically, we will talk about the Vlasov equation and its applications in inertial confinement fusion. We will also discuss stability problems in magnetohydrodynamics. We will then move to computational fluid dynamics and discuss the lattice Boltmann method. We will talk about current classical approaches to solve them and their approximate complexity. Finally, we will present some interesting and promising quantum approaches to solve these problems.

Tom LUBINSKI, QED-C, Senior Technical Advisor (QCI), Committee Lead, Quantum Computing Standards and Benchmarks (QED-C) - Application Performance Exploration Using the QED-C Quantum Computing Benchmark Framework

This talk provides an overview of research and development efforts, published results, and future plans of the Quantum Economic Development Consortium (QED-C) in establishing an open-source framework for assessing the performance of quantum computing systems through the use of quantum algorithms and applications. We review the requirements and challenges in developing these methodologies from the perspective of both the developer and the end user. We show how these benchmarks are structured to sweep over a range of problem sizes and input characteristics, systematically capturing key performance metrics, i.e. quality of result, execution effectiveness (tradeoff between quality and runtime), and resources consumed, with supporting infrastructure and abstractions that make them accessible to a broad audience of users. Looking to the future, we introduce upcoming work and proposals for additional efforts to facilitate the exploration of quantum algorithmic options and their impact on performance in this continually evolving benchmarking framework.

Laura SCHULZ, Leibniz Supercomputing Centre, Germany (LRZ), Head of Quantum Computing and Technologies - Q@LRZ: The Arrival, Applicability and Assessment of Quantum to HPC

Quantum systems are now entering HPC centers and their integration as accelerators into HPC workflows is underway. Given their early technological state, diverse architectures and rapid evolution, quantum accelerators pose unique challenges for reliable and useful benchmarks to characterize their performance and error profiles. Further, as we integrate quantum processors into HPC, there is a growing need for benchmarks tailored to these hybrid workflows to accurately characterize the interplay of these resources and guide optimization and resource allocation. This talk will explore the overall state of quantum-HPC integration, the challenges of benchmarking quantum and quantum-HPC systems, and our efforts at LRZ on these topics.

Nathan SHAMMAH, UNITARY FUND (MetriQ)- Metriq: a web platform and community for quantum technology benchmarks

There is little or no consensus on what constitutes a representative and useful benchmark for quantum computers. Literature on quantum benchmarks exists in disparate journals and repositories, comparison between published ad hoc benchmark metrics is difficult, and there is no central community hub to vet and discuss published results. Despite this, many hardware providers developing prototypes are already attempting to pivot to commercialization of NISQ devices. The Metriq platform (https://metriq.info) is an open-source community hub and repository for review of the capabilities of quantum computers in general public use and in peer-reviewed literature. Metriq fits open-ended community-contributed research literature results to a simple standardized schema that enables automatic comparison and graphing of quantum technologies across the field on common "tasks," comparing "methods" operating on "platforms," achieving "results" that can be fairly compared over time. Through Unitary Fund's online community-building initiative and support by a recently inaugurated quantum open-benchmark committee, we aim to simplify publication and tracking of quantum benchmarks.

Franck PHILLIPSON, NATO- Comparing discrete optimization solvers – how to make a fair comparison

NATO has initiated a series of workgroups focusing on the burgeoning realm of quantum applications, seeking to harness the transformative potential of quantum technologies across various domains. Among these, a prominent initiative revolves around the exploration of quantum computing applications within the sphere of situational awareness—a domain where rapid and optimal decision-making based on sensor data holds paramount importance. I will tell something about this workgroup and its targets.

One of the objectives of this workgroup is the demonstration of quantum speedup (and other benefits) and its consequential benefits within the realm of situational awareness. Through rigorous experimentation and analysis, the group seeks to showcase the tangible advantages afforded by quantum computing methodologies in processing sensor information and facilitating real-time decision-making under complex and dynamic operational environments.

Of particular interest is the exploration of combinatorial optimization—a fundamental aspect of situational awareness operations. I will dive a bit into what I define to be a fair comparison of performance of the combination of (quantum) hardware and algorithms within the field of combinatorial optimization.

Muhammad USMAN, CSIRO- Benchmarking quantum computers by error correction syndrome measurements

With quantum computers rapidly approaching qualities and scales for utility and useful applications, it is important to develop new benchmarking methods to evaluate their performance in the presence of noise or errors. In this work, we have assessed the performance of IBM quantum computers through heavy-hexagon code syndrome measurements with increasing circuit sizes up to 23 qubits, against the error assumptions underpinning code threshold calculations. Data from 16 repeated syndrome measurement cycles was found to be inconsistent with a uniform depolarizing noise model, favouring instead biased and inhomogeneous noise models. These results highlight the non-trivial structure which may be present in the noise of quantum error correction circuits, revealed by operator measurement statistics, and support the development of noise-tailored codes and decoders to adapt. Our work provides crucial information about noise in the NISQ era quantum computers which will pave the way for future implementation of fault-tolerant applications.

Joseph EMERSON, KEYSIGHT - Benchmarking Quantum Benchmarks and the case for Circuit Benchmarking as a universal, flexible and scalable benchmarking framework

I will review the strengths and weaknesses of leading quantum benchmarking methods, comparing randomized component level and system level vs application-level approaches, and then describe a new universal approach to benchmarking that unifies these two approaches, overcomes existing limitations and paves a path to a standard benchmarking methodology that applies from current NISQ to future FT-QEC capabilities across all quantum hardware platforms.

Jeanette LORENZ, Fraunhoffer -IKS, Head of Quantum-enhanced AI department in Fraunhofer IKS - What we can learn from applications for the development of quantum computing – the German perspective

With the increasing availability of quantum computers, although still limited in the number of qubits and quality, we understand more and more which applications might or might not profit from using quantum computing. Also, studying the potential of quantum computing for applications guides the further development of quantum hardware and software. This is further emphasized by the increasing activities towards application-centric benchmarks.

Alexandru PALER, Aalto University, PI in the Darpa projects- What algorithms should we study with 100 QUBITS and 1M logical gates?

In order to co-design algorithms with hundreds of qubits and millions of gates, one should start from the following research questions related to the execution of simpler protocols: a) how are injection protocols reflected in the decoding of correlated errors?; b) do logical qubits suffer from novel/unexpected types of errors, and if so, what is the effect of these errors on the structure of the fault-tolerance compilation primitives? c) what logical cycle times are to be expected based on the underlying architecture, and how much of an improvement is necessary for lowering the resource counts? In the first part of the talk, we will present a realistic software stack that is already available and can be used for automating the search and co-design of algorithms. In order to answer the research questions, new models, methods and (software) tools need to be researched and implemented. These aspects are discussed in the second part of the talk. The methods and results presented herein were developed partially within projects (where the speaker is a PI) funded by the DARPA Quantum Benchmarking program, QuantERA and Google.

Frédéric BARBARESCO, Thales, member of GIFAS-R&D Commission- Recommendations on Quantum Computing from GIFAS Report on quantum technologies for Aerospace-Defense applications (Thales, member of GIFAS-R&D Commission)

This report was written at the request of the GIFAS R&D commission by a working group dedicated to quantum technologies and made up of representatives of main French industry players in the field, under the coordination of ONERA. This report defines the major contributions for the quantum technologies, the targeted applications from aerospace-defense sector and the associated calendar horizons as well as recommendations for the sector and for the national quantum strategy. This GIFAS R&D Commission working group led by ONERA with 14 GIFAS companies has elaborated recommendations on sensors, communication, computing and enabling technologies. We will present here main recommendations about quantum computing.

Mitsuhisa SATO, RIKEN – Japon - JHPC quantum project for Quantum-supercomputer hybrid computing platform

As the number of qubits in advanced quantum computers is getting larger over 100 qubits, demands for the integration of quantum computers and HPC are gradually growing. RIKEN R-CCS has been working on several projects to build a platform which integrates quantum computers and HPC together. Recently, we have started a new project, JHPC-quantum project, funded by NEDO with the title "Research and Development of quantum-supercomputers hybrid platform for exploration of uncharted computable capabilities". In this project, we are going to design and build a quantum-supercomputer hybrid computing platform which integrates different kinds of quantum computers, IBM and Quantinuum, with supercomputers including Fugaku. In this talk, the overview of the JHPC-quantum projects will be presented.

Marvin ERDMANN, The BMW Group's Perspective on Application-driven Benchmarking

The Quantum Computing Application Benchmarking (QUARK) framework is an open-source project initiated in 2021 by the BMW Group. Its modular architecture facilitates the integration of new application kernels and the addition of modules on deeper layers like the classical or quantum hardware used for benchmarking runs. A growing community of developers from academia and industry is contributing to the framework and is using QUARK for research projects and to evaluate the performances of quantum algorithms and hardware for combinatorial optimization and quantum machine learning use cases. Learn more about QUARK's application-oriented structure and how it is used for state-of-the-art quantum computing benchmarks!

Jose MIRALLES, CUCO- Benchmarking Energy Consumption of Quantum Computers

Present HPC centers are reaching their limits in computing capacity incurring huge overheads both in terms of price and energy demands. Quantum computation's advantage is typically assessed based on computational runtimes. However, the concept of quantum advantage encompasses dimensions beyond speed, notably energy consumption. In this talk we will discuss our recent efforts in benchmarking the energy consumption of both HPC systems and superconducting-based quantum computers for various comparable tasks. We aim to consider every relevant aspect required in the execution process of both systems for a complete comparison. Part of these results have been developed in the context of Qilimanjaro Quantum Tech and Barcelona Supercomputing Center's contribution in the Spanish CUCO project (cuco.tech/en), which aims to evaluate the capabilities of quantum computing in strategic industries, including its application in the path to a more sustainable way of doing heavy computations.

Rawad MEZHER, Quandela - Benchmarking photonic quantum devices

For near-term quantum devices, an important challenge is to develop methods to certify that noise levels are low enough to allow potentially useful applications to be carried out. In this presentation, I will discuss several such methods tailored to photonic quantum devices, and designed to assess generic performance, as well as performance of specific gates.

Paul MAGNARD, Quantum Physicist and Cécile PERRAULT, Alice&Bob - Assessing the performance of Dissipative Cat Qubits

The massive hardware overhead required to implement quantum error correction remains a big roadblock towards the realization of a fault-tolerant, universal quantum computer. Bosonic codes are a promising approach to decrease significantly the hardware overhead by implementing a first layer of error correction at the physical qubit level.

In particular, dissipative cat qubits suppress bit-flip errors exponentially over orders of magnitude, while increasing phase-flip errors linearly. The average fidelity of a cat qubit is therefore degraded, yet it is estimated that this approach would allow to run Shor's algorithm with 60 times less physical qubits than needed with the surface code. Cat qubits seem both worse and better than non-biased « standard » qubits. How can we quantitatively compare the advantage of such biased-noise ?

In his talk, we will show a method to answer this question. We show a simple model explaining how a few key cat-qubit-operation error quantities affect the logical error of a repetition code built from those operations, and how to measure them. This allows to quantitatively benchmark the quality of noise-biased cat qubits and compare it to non-biased qubits using the resulting logical error in a quantum error correction code. We will present current experimental benchmark results, and discuss the perspectives and roadblocks towards building a cat-qubit-based logical qubit under threshold.

Benoit VERMERSCH, Université Grenoble Alpes - Benchmarking quantum devices with the randomized measurement toolbox

I will review theoretical and experimental progress in developing protocols that verify quantum devices based on randomized measurements [1]. I will show that these protocols are now routinely used in various quantum processing platforms, giving in particular faithful estimations of quantum state fidelities, entanglement quantifiers, etc. I will also discuss our current efforts in developing high-quality & flexible codes for post-processing randomized measurements.

[1]: The randomized measurement toolbox. Andreas Elben, Steven T. Flammia, Hsin-Yuan Huang, Richard Kueng, John Preskill, Benoît Vermersch & Peter Zoller Nature Reviews Physics volume 5, pages 9–24 (2023)

Daniel MILLS, QUANTINUUM, Research Scientist - Benchmarking the Quantinuum Stack

We present results of, and motivations for, some of the benchmarks conducted at different layers of the Quantinuum quantum computer stack. This includes component level benchmarks, such as of the gate fidelity, and benchmarks of our enabling technology, such as the TKET compiler.

We discuss results of the holistic full stack benchmarks performed, including quantum volume, and detail the standardisation efforts we have participated in and envision for the future.