Headline Sponsor: Aalto University

unitaryCON 2024 - September 12-14, Helsinki, Finland

Time	Wed Sept 11	Thu Sept 12	Fri Sept 13	Sat Sept 14
Location	**Building:** Dipoli	**RM:** Jeti **Building**: Otakaari	**RM:** Lumituuli **Building:** Dipoli	**RM:** Jeti **Building**: Otakaari
9:00 - 9:30	Green: Open Hardware Purple: Benchmarking / Resource Estimation Blue: Scaleable and Error Resilient Compilation	Registration	Luciano Bello – IBM Quantum	Bruno Schmitt – NVIDIA
9:30 - 09:45		Welcome by Unitary Fund		
9:50-10:35		Unitary Fund Overview	Korbinian Kottmann – Xanadu	Eduardo Maschio – PASQAL
10:35 - 11:05		Coffee Break	Coffee Break	Coffee Break
11:05 - 11:50		Unitary Fund - Metriq	Unitary Fund - Mitiq	Jake Malliaros – OQD
11:55 - 12:30		Mathias Weiden – BQSKit	Rochisha Agarwal – QuTiP	Aaron Trowbridge – CMU
12:30 - 12:45		Lunch	Lunch	UCC - Jordan Sullivan, Unitary Fund
12:45 - 14:00				Lunch
14:00 - 15:00		Max Aalto - Open Quantum	Free Pitches	End of Event
15:05 - 15:35	Hotel check-in and Welcome at Dipoli Building	Stefano Carrazza - Qibo	Tyson Jones – QuEST	
15:35 - 16:20		Free discussions + Coffee	Free discussions + Coffee	
16:25 - 17:00		Harshit Gupta - QBraid	UF projects lightning talks • GA-QAS • OpenQAOA • Project 3	
19:00 - 20:30	Welcome Reception	Free evening	Free Evening	

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Institute Q

Abstracts

Thursday, September 12, 2024

Speaker: Dan Strano, Unitary Fund
Title: Metriq: a web platform and community for quantum technology benchmarks
Abstract: There is little or no consensus on what constitutes a representative and useful benchmark for quantum computers at the current “noisy intermediate-scale quantum” (NISQ) era of hardware research and development. 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) aims to be a 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, Metriq draws together researchers, professionals, and enthusiasts to build a Wiki-like library of published and independent quantum benchmarks.

Speaker: Mathias Weiden, BQSKit
Title: Compiling Resource-Efficient Quantum Programs with BQSKit
Abstract: Quantum hardware is experiencing a boon leading to more chip variety, configurations with higher fidelities, and demonstrations of quantum error correction below fault-tolerance thresholds. While ultimately, this will translate to a boon for the entire field of quantum computing, it presents two problems. First, algorithm designers and users must make more difficult choices between potential hardware vendors. Second, this places more of the overall burden of end-to-end quantum applications on the software stacks, specifically the quantum compiler. The Berkeley Quantum Synthesis Toolkit (BQSKit) is a powerful and portable compiler with a proven ability to alleviate these issues and translate recent hardware successes up to the algorithm level. In this talk, I will first introduce the idea of numerical instantiation, a core primitive of BQSKit compilation. Next I will highlight several advancements and applications of synthesis including permutation aware synthesis, QFactor instantiation, seeded synthesis, principled circuit approximation, application motivated gate set evaluation, and synthesis for fault-tolerant gate sets.

Speaker: Max Aalto, OpenQuantum

Abstract: OpenQuantum is a complete, simple, low-cost, and open-source blueprint for a rubidium magneto-optical trap. The initiative provides high-quality educational materials alongside CAD models, electronics schematics, control firmware, and assembly instructions, to substantially lower the barrier to entry for building a teaching lab for quantum engineering. Our goal is to accelerate the growth of the fields of atomic physics and quantum information by spreading tacit knowledge, providing robust solutions to common problems, and developing scalable manufacturing for high supply chain risk components.

Speaker: Stefano Carrazza
Title: Qibo: an open-source hybrid quantum operating system
Abstract: The growing interest in quantum computing and the recent progress of quantum hardware devices motivates the development of new advanced computational tools focused on performance and usage simplicity. Therefore, in this talk, we present Qibo, an open-source quantum computing middleware framework which provides to users a standardized set of tools for the design, simulation and execution of quantum circuits on classical and quantum hardware [1]. We describe the major backend libraries integrated in Qibo for quantum simulation [2], quantum hardware control and calibration [3]. We show benchmark results related to the simulation and control performance of Qibo and provide examples of full-stack quantum computing algorithms developed in the context of particle physics applications [4]. Finally, we conclude by summarizing the new features planned for the next major release and by providing an overview of Qibo's integration into national quantum research initiatives around the world.

[1] S. Efthymiou et al., "Qibo: a framework for quantum simulation with hardware acceleration", Quantum Sci. Technol. 7 015018 (2020).

[2] S. Efthymiou et al., "Quantum simulation with just-in-time compilation", Quantum 6, 814 (2022)

[3] S. Efthymiou et al., "Qibolab: an open-source hybrid quantum operating system", Quantum 8, 1247 (2024)

[4] A. Pérez-Salinas et al., "Determining the proton content with a quantum computer", Phys. Rev. D 103, 034027 (2021)

Speaker: Harshit Gupta, QBraid
Abstract: qBraid is a cloud-based platform for quantum computing that provides software tools for researchers and developers to access quantum and classical resources in a unified environment. Its major offerings include a customized JupyterLab environment tailored for quantum development, the qBraid SDK that supports platform-agnostic quantum computing across various hardware and simulators, and qBraid Compute, an integrated platform providing

access to over 20 quantum computers and simulators. Built with the goal of simplifying quantum software development, qBraid allows users to execute programs without managing complex dependencies and easily interpret results using the qBraid SDK. Additional tools include the qBraid CLI, a command-line interface for platform interactions, and the qBraid-QIR package, which facilitates conversions to Quantum Intermediate Representation (QIR) from higher-level abstractions.

Friday, September 13, 2024

Speaker: Luciano Bello, IBM
Title:
Abstract: Last UnitaryCon, we announced the first major version of Qiskit, the leading open-source quantum computing framework. This year, we will explore the journey of the 1.* series, focusing on its evolution and impact, while highlighting performance improvements. With over 546 contributors, 6.5 million downloads, and citations in more than 1,600 research papers, Qiskit has solidified its leadership as the most widely adopted quantum computing framework, as confirmed by Unitary Fund surveys. This presentation will discuss key advancements, including dynamic circuits, memory optimizations, and AI-enhanced transpilation. The session will offer a comprehensive overview of Qiskit's capabilities, its central role in advancing quantum research and development across various domains, and explore potential future directions.

Speaker: Korbinian Kottmann, Xanadu
Title: Software-driven research with PennyLane
Abstract: There is a natural symbiosis between doing advanced quantum research and quantum software development in the same org.
I am going to show you how leveraging this interplay has led to new scientific results while providing advanced new software features in PennyLane.

Speaker: Alessandro Cosentino, Unitary Fund
Title: Lessons from building a cross-platform error mitigating toolkit
Abstract: Since its inception in 2020, Mitiq has been a cross-platform error mitigating toolkit, designed to serve both quantum software developers and Quantum Error Mitigation (QEM) researchers. In this talk, we will explore the key design principles that have enabled Mitiq to maintain a stable and user-friendly API amidst the fast-paced developments in quantum computing. We will also delve into the challenges encountered while integrating new features and share valuable insights gained from over 50 interviews with professionals across the quantum computing landscape. This session aims to provide practical takeaways for developers looking to build resilient and adaptable quantum software.

Speaker: Rochisha Agarwal, QuTiP
Title: Accelerating Quantum Simulations with QuTiP and QuTiP-JAX
Abstract: QuTiP is an open-source framework for simulating quantum systems, widely used in quantum research. This talk will briefly introduce QuTiP's core functionalities, along with QuTiP-QIP for quantum information processing, QuTiP-QOC for quantum optimal control, and QuTiP-JAX. The focus will be on QuTiP-JAX, which integrates JAX for automatic differentiation, just-in-time compilation, and GPU acceleration. We'll explore how QuTiP-JAX enhances quantum

simulations and optimization tasks, providing a powerful tool for advancing quantum computing research.

Lightning Talks:

- **Speaker:** Viet Nguyen, GA-QAS
  Abstract: This talk presents the method and results of GA-QAS for multi-target quantum compilation applications, which has important implications for variational methods on emulating quantum evolution under varying physical parameters such as time, temperatures, atomic distances, etc. Generally, the GA-QAS purposefully searches for an efficient quantum circuit to simulate multiple target states created by the variation in the Hamiltonian's physical parameters. Our benchmarks and case studies demonstrate the algorithm's effectiveness and flexibility in a wide range of problems, including but not limited to thermal state preparation (TSP), time-dependent quantum dynamic simulation (TD-QDS), and variational quantum eigensolver (VQE).

- **Speaker:** Alejandro Montañez-Barrera, OpenQAOA
  Abstract: Solving combinatorial optimization problems (COP) using quantum computation usually requires encoding them into the quadratic unconstrained binary optimization (QUBO) formulation. In this talk, I will present results on the set of COPs included in the OpenQAOA library as part of the microgrant project "Optimization problems in OpenQAOA".

Speaker: Tyson Jones
Title: The QuEST to desperately maintain the relevance of statevector simulations
Abstract: There are many algorithms and paradigms to classically simulate quantum computers. The full-state method numerically instantiates the quantum state as dense vectors and matrices. This teeny-brain method prescribes upfront exponentially growing memory and runtime costs. But computational complexity isn't everything - in the right settings, full-state simulation may actually be galactic-brain. This talk will desperately attempt to motivate the continued relevance of full-state simulators in order to showcase QuEST, a highly-parallel simulator of statevectors and density matrices.

Saturday, September 14, 2024

Speaker: Bruno Schmitt, NVDIA
Abstract: As high-performance computing (HPC) evolves towards heterogeneous architectures, NVIDIA CUDA-Q is at the forefront, enabling a dynamic workflow with a kernel-based programming model. Indeed, we are building CUDA-Q for hybrid application development, offering a unified programming model designed for a hybrid setting where CPUs, GPUs, and QPUs work together. It consists of language extensions for Python and C++ and a system-level toolchain that enables application acceleration.

We'll delve into some distinguishing and future-forward features of CUDA-Q. Talk about its compiler toolchain, the intermediate representation, and the language extensions currently supported in Python and C++.

Speaker: Eduardo Maschio, Pasqal
Title
Abstract:

Speaker: Jake Malliaros, Open Quantum Design
Title:
Abstract: Open Quantum Design (OQD) is developing an open-source, full-stack trapped-ion quantum computer. We present two devices: Bloodstone (30-50 171Yb+ ions) and Beryl (16 133Ba+ ions), both featuring individual qubit addressing. Our control system, based on ARTIQ and DAX, offers digital, analog, and atomic abstraction layers. We've extended these frameworks with a modular architecture to facilitate component transfer between setups. The compiler infrastructure translates high-level quantum algorithms to hardware instructions through multiple passes: canonicalization, analysis, verification, optimization, and lowering. All software and hardware designs will be released under the Apache 2.0 license. This open approach aims to accelerate quantum computing research by enabling wider participation and collaboration in the field. We will discuss the technical challenges, current capabilities, and future directions of this project.

Speaker: Aaron Trowbridge, CMU
Title:
Abstract: Open-source quantum optimal control methods are gaining importance as the greater open quantum hardware ecosystem grows. Emerging hardware platforms including neutral atoms, cat qubits, fluxonium qubits, and sensors require specially designed pulses. Also, new applications of pulse level control, including analog quantum machine learning methods, are emerging. In this talk, we will highlight the current state of the Piccolo.jl project, our ongoing collaborative research efforts, and future directions for the project ecosystem.

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