Abstract Booklet

Quantum Computing User Forum

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1. KEYNOTE TALKS

Neyenhuis, Brian	Quantinuum	8/12, 1pm

QUANTINUUM'S TRAPPED-ION QUANTUM COMPUTERS

Quantinuum's H-series Quantum Computers use a fully reconfigurable array of trapped atomic-ions to provide universal quantum computation with high-fidelity operations, arbitrary connectivity, and mid-circuit measurement. Brian will give a brief overview of the unique features of our machines along with specifications and performance metrics. Brian will outline some of our current thoughts on promising places to achieve near-term quantum advantage and present our long-range roadmap to large-scale fault-tolerant quantum computing.

Mezzacapo, Antonio	IBM	8/13, 1pm

CHEMISTRY BEYOND THE REACH OF EXACT SOLUTIONS OF THE SCHROEDINGER EQUATION ON A QUANTUM-CENTRIC SUPERCOMPUTER

We present quantum computations of chemistry that go beyond problem sizes amenable to current state-of-the-art exact diagonalization methods. Our results are obtained in a quantum-centric supercomputing architecture, using 6400 nodes of the Fugaku supercomputer to assist an IBM Heron quantum processor. We simulate the N2 triple bond breaking in a correlation-consistent cc-pVDZ basis set, and the active-space electronic structure of [2Fe–2S] and [4Fe–4S] clusters, using 58, 45 and 77 qubits respectively, with quantum circuits of up to 10570 (3590 2-qubit) quantum gates.. The experiments performed establish an unconditional quality metric for quantum advantage, certifiable by classical computers at polynomial cost.

Gamble, John	IonQ	8/14, 1pm

SCALABLE TRAPPED-ION QUANTUM COMPUTING WITH IONQ

Quantum computing has the potential to revolutionize the way we solve many problems, ranging from analyzing chemical reactions to cryptography. IonQ's commercial quantum computers use trapped ions as qubits, featuring high-fidelity operations across long chains of qubits. In this talk, I will describe how IonQ's hardware works and highlight recent machine performance results. I will discuss our roadmap and how our architecture is built to scale to larger problem sizes. Finally, I will review some recent use cases that highlight how our focus on performance, scale, and enterprise-grade technology is having impact.

Mutus, Josh	Rigetti	8/15, 1pm

DISTRIBUTED QUANTUM COMPUTING, TOMORROW AND TODAY

Quantum computing promises to solve problems intractable on today's HPC machines. To the best of our knowledge, fault tolerant computations will require large amounts of quantum computing resources. Because of this, even early fault tolerant machines will likely be distributed; consisting of many fault tolerant quantum computing modules working together coherently and classically with conventional computing resources on a single application. I'll share recent results of resource estimation on such large scale problems. I'll discuss how experiments today in hybrid quantum-classical HPC applications in areas such as simulation, optimization and error correction can inform future architectures for distributed quantum computation.

2. CONTRIBUTED TALKS

Hisham Amer	Virginia Tech

EXPERIMENTAL REALIZATION OF DYNAMICALLY CORRECTED GATES ON IBM HARDWARE

Despite the steady rise in the performance of superconducting devices, gate fidelities have yet to break error thresholds, or reach the robustness needed for practical quantum computing applications. Noise-induced gate errors play a key role in this setback. One promising approach to suppressing such errors is through designing control fields that have intrinsic error suppression qualities. Here, we demonstrate on IBM‚Äôs superconducting devices dynamically corrected robust gates using control pulses that are designed for dynamical error suppression. This robustness is achieved by mapping quantum evolution to closed space curves, based on the theoretical machinery developed in our Space Curve Quantum Control (SCQC) formalism. We experimentally demonstrate that our single qubit gates are more robust compared to native IBM gates.

Jan Balewski	NERSC/Lawrence Berkeley National Laboratory

CLASSIFICATION OF NON-LINEARLY SEPERABLE DATASETS OF NISQ DEVICES

The utility of integrating a quantum processor within a machine learning pipeline is an area of active research. This study evaluates performance of quantum machine learning in classifying synthetically generated 2-dimensional datasets, both linearly and non-linearly separable. We employed the PennyLane framework to train various parametrized quantum circuits, leveraging efficient SU3, alternating CNOT, and CPhase ansatzes. Our research utilized a variety of synthetic datasets, such as concentric circles, XOR square, two spirals, and moons dataset. The models were trained using the PennyLane state vector simulator then tested in inference mode on multiple IBM quantum backends. We examine how inference accuracy varies with hyperparameters, including the ansatz type, number of ansatz layers and qubits, choice of optimizer, learning rate schedule, and the type of backend used. We found that certain combinations of hyperparameters enabled us to achieve up to 90% accuracy on selected quantum hardware across several datasets.

Anthony Ciavarella	Lawrence Berkeley National Laboratory

CHARACTERIZING A NON-EQUILIBRIUM PHASE TRANSITION ON A QUANTUM COMPUTER

A Hamiltonian lattice formulation of SU(3) gauge theory opens the possibility for quantum simulations of the non-perturbative dynamics of QCD. By parametrizing the gauge invariant Hilbert space in terms of plaquette degrees of freedom, we show how the Hilbert space and interactions can be expanded in inverse powers of N_c. At leading order in this expansion, the Hamiltonian simplifies dramatically, both in the required size of the Hilbert space as well as the type of interactions involved. Adding a truncation of the resulting Hilbert space in terms of local energy states we give explicit constructions that allow simple representations of SU(3) gauge fields on qubits and qutrits. This formulation allows a simulation of the real time dynamics of a SU(3) lattice gauge theory on a 5√ó5 and 8√ó8 lattice on ibm_torino with a CNOT depth of 113.

Yuhua Duan	National Energy Technology Laboratory

MODELING SINGLET FISSION ON A QUANTUM COMPUTER

Growing interest in quantum computing and simulations have created opportunities for its deployment to improve processes pertaining to energy production, distribution, and consumption. To fully address the status and future challenges of quantum information science (QIS) applied within the energy sector, in this presentation, we firstly summarize recent advancements on the applications of quantum computing to energy infrastructure and materials, complex energy system processes, advanced manufacturing, and energy system security. Then, we will demonstrate the results of quantum computing both on a simulator and a quantum device accessing from OLCF. Our first example is to use the variational quantum eigensolver (VQE) with a unitary coupled cluster with singles and doubles (UCCSD) ansatz to simulate a series of LixHyq molecules (q=-1, 0, +1). The obtained results showed that the quantum computing VQE-UCCSD is comparable to classical CCSD for small systems like LiH with respect to full configuration interaction (FCI). Targeting on CO2 capture application, our second example is to use VQE to quantify molecular vibrational energies and reaction pathways between CO2 and a simplified amine-based solvent model,ÄîNH3 to form H2NCOOH. This research showcases quantum computing applications in the study of CO2 capture reactions.

Suman Debnath	Oak Ridge National Laboratory

RESEARCH ON USE OF QUANTUM COMPUTERS IN POWER GRID

This talk will provide an overview of the ongoing research on use of quantum computers in power grid problems related to simulations and optimizations and the way forward. It will also briefly provide information on facilities being evaluated for evaluating impact of quantum technologies on power grid.

Esam El-Araby	University of Kansas

MULTIDIMENSIONAL QUANTUM CONVOLUTION FOR VARIATIONAL QUANTUM ALGORITHMS

The convolution operation plays a vital role in a wide range of critical algorithms across various domains, such as digital image processing, convolutional neural networks, and quantum machine learning. In existing implementations, particularly in quantum neural networks, convolution operations are usually approximated by the application of filters with data strides that are equal to the filter window sizes. One challenge with these implementations is preserving the spatial and temporal localities of the input features, specifically for data with higher dimensions. In addition, the deep circuits required to perform quantum convolution with a unity stride, especially for multidimensional data, increase the risk of violating decoherence constraints. In this work, we propose depth-optimized circuits for performing generalized multidimensional quantum convolution operations with unity stride targeting applications that process data with high dimensions, such as hyperspectral imagery and remote sensing. We experimentally evaluate and demonstrate the applicability of the proposed techniques by using real-world, high-resolution, multidimensional image data on a state-of-the-art quantum simulator from IBM Quantum.

Jim Furches	Virginia Tech

EVALUATING NON-LOCAL QUANTUM STRATEGIES ON NISQ HARDWARE: CONNECTING BENCHMARKS TO PERFORMANCE

In a nonlocal game, two noncommunicating players cooperate to convince a referee that they possess a strategy that does not violate the rules of the game. Quantum strategies allow players to optimally win some games by performing joint measurements on a shared entangled state, but computing these strategies can be challenging. In a recent work (arXiv:2311.01363) we developed a variational algorithm for computing strategies of nonlocal games and showed that it can yield optimal strategies for small examples of both convex and non-convex games. Our algorithm is capable of generating a short-depth circuit that implements an optimal quantum strategy for a graph coloring game and can be run on near-term quantum computers. We argue that these circuits are useful hardware benchmarks because of their sensitivity to 2-qubit gate noise and application to self-testing. In this talk we provide concise demonstrations on how low-level benchmarks connect to high-level application performance by running these strategies on Rigetti quantum computers along with several benchmarks for: correlated noise characterization, entangled state preparation.

Sahil Gulania	Argonne National Laboratory

QUANTUM ERROR MITIGATION AND CORRECTION MEDIATED BY YANG-BAXTER EQUATION AND ARTIFICIAL NEURAL NETWORK

Artificial error mitigation harmonizes classical and quantum computing, capitalizing on their individual strengths to offset weaknesses. Classical algorithms analyze and model errors in quantum computations, guiding corrective actions on quantum states to enhance reliability without the overhead of traditional error correction codes. This study demonstrates how machine learning and zero-noise extrapolation (ZNE) reduce quantum noise. ZNE faces challenges when generating noisy data for large quantum circuits and qubit systems. Focusing on quantum time dynamics (QTD) simulations, errors from unitary folding (a technique to generate noisy data in ZNE) can lead to undesired results. Also, implementing ZNE at each time step introduces significant overhead. Our solution uses artificial neural networks to master a subset of time steps and rectify the remaining dynamics. Leveraging the Yang-Baxter equation [1, 2, 3] for circuit compression provides control over depth and generates extra noise data without additional numerical errors.

Weiwen Jiang	George Mason University

QDA: QUANTUM DESIGN AUTOMATION TOWARD PRACTICAL QUANTUM COMPUTING

Before the advent of Electronic Design Automation (EDA) in the mid-1970s, integrated circuits were meticulously crafted by hand, relying on manual layout processes. Similarly, the field of quantum computing is presently in its nascent stage, marked by the prevalent use of ad-hoc and manual-design approaches in quantum circuit design. This methodology, reminiscent of the early days of classical integrated circuits, presents a challenge to the evolution of practical quantum computing. In response to this challenge, there is a growing imperative for the development of a quantum analog to EDA --- Quantum Design Automation (QDA). This quantum-centric EDA aims to provide a systematic and automated framework for the design of quantum circuits, marking a crucial step towards overcoming the current impediments in the path to practical quantum computing. This talk undertakes a comprehensive comparison between classical and quantum computing design stacks, elucidating the intricacies introduced by qubit properties. Addressing the impact of unstable noise becomes central, providing insights into the necessities, obstacles, and opportunities in QDA. The talk outlines automated optimizations at various layers to tailor circuits to current noise, ultimately enhancing fidelity.

Seongmin Kim	Oak Ridge National Laboratory

PERFORMANCE ANALYSIS OF QAOA FOR METAMATERIAL DESIGN ON HPC AND QUANTUM SYSTEMS

Optimizing geometrical features of metamaterials is important to achieve high performance, but their complex parametric spaces lead to an explosion of optimization spaces, making optimization processes impractical in realistic time scales. Quantum computing offers a promising solution to such challenges, with the Quantum Approximate Optimization Algorithm (QAOA) standing out as one of the most promising quantum algorithms in the noise intermediate-scale quantum (NISQ) era to solve optimization problems. Quantum simulators, which emulate and explore quantum behavior to solve given problems (or quantum circuits), are valuable tools for running quantum algorithms in the NISQ era. Here, we analyze the performance of quantum simulators for metamaterial design. The operational performance of QAOA may vary for each simulator since the operating mechanisms of simulators are different, thus it is required to analyze the QAOA performance on each simulator. Furthermore, quantum simulators can work more efficiently when submitting or executing hybrid jobs on an HPC system, such as OLCF Frontier. Hence, we comprehensively analyze the performance of the QAOA designed for optimizing metamaterials on different quantum simulators (e.g., qasm and statevector) on a local computer or HPC and quantum systems. This study provides valuable insights into the most effective quantum simulator for QAOA in optimizing metamaterials and the advantage of employing an HPC system to run quantum algorithms.

Katie Klymko	Lawrence Berkeley National Laboratory

QUANTUM COMPUTATION WITH NEUTRAL ATOMS: KEY OUTCOMES FROM NERSC'S FIRST R&D COLLABORATION WITH QUERA COMPUTING

In this talk we will describe the first year of NERSC’s collaboration with QuEra Computing which was focused on exploring the potential for using neutral atom hardware to accelerate certain scientific applications of interest. We focused on two main problems: solving the ground state phase diagram of the Lieb lattice and studying the dynamics of false vacuum decay. I will describe our results, including experimental data from Aquila, QuEra’s analog neutral atom hardware. I will also describe our plans going forward.

Phil Lotshaw	Oak Ridge National Laboratory

QUANTUM APPROXIMATE OPTIMIZATION

Quantum computers might be useful for approximately solving NP-hard combinatorial optimization problems, which could help society by improving the efficiency of diverse tasks such as logistics and scheduling. I will discuss my ongoing research into the quantum approximate optimization algorithm, its variants, and related ideas that are at the forefront of near-term quantum algorithm research for addressing these problems.

Elijah Pelofske	Los Alamos National Laboratory

HIGH-ROUND QAOA FOR MAX-SAT ON TRAPPED ION NISQ DEVICES

The Quantum Alternating Operator Ansatz (QAOA) is a hybrid classical-quantum algorithm that aims to sample the optimal solution(s) of discrete combinatorial optimization problems. We present optimized QAOA circuit constructions for sampling MAX k-SAT problems, specifically for k=3 and k=4. The novel 4-SAT QAOA circuit construction we present uses measurement based uncomputation, followed by classical feed forward conditional operations. The QAOA circuit parameters for 3-SAT are optimized via exact classical (noise-free) simulation, using HPC resources to simulate up to 20 rounds on 10 qubits. In order to explore the limits of current NISQ devices we execute these optimized QAOA circuits for random 3-SAT test instances with clause-to-variable ratio 4 on four trapped ion quantum computers: Quantinuum H1-1 (20 qubits), IonQ Harmony (11 qubits), IonQ Aria 1 (25 qubits), and IonQ Forte (30 qubits). The QAOA circuits that are executed include n=10 up to p=20, and n=22 for p=1 and p=2. The high round circuits use upwards of 9,000 individual gate instructions, making these some of the largest QAOA circuits executed on NISQ devices. Our main finding is that current NISQ devices perform best at low round counts (i.e., p=1,,Ä¶,5) and then -- as expected due to noise -- gradually start returning satisfiability truth assignments that are no better than randomly picked solutions as the number of QAOA rounds are further increased.

Toño Coello Perez	Oak Ridge National Laboratory

EXPLORING AND BENCHMARKING PROSPECTS FOR HPC-QUANTUM INTEGRATION ON A LEADERSHIP-SCALE COMPUTING PLATFORM

Quantum computers hold promise to solve problems that are traditionally hard to explore on classical hardware. Both current noisy and future error-corrected quantum devices will have to work closely in tandem with classical computers. In this talk we explore the viability of integrating quantum hardware into the Summit leadership-scale supercomputing system by implementing the QStone benchmarking suite. The quantum device role is at this stage played by a classical computer connected to Riverlane-provided ASIC electronics.

Sanket Sharma	University of Tennessee-Knoxville

TWO-NUCLEON SCATTERING ON A QUANTUM COMPUTER

I will discuss our recent work, where we calculate the scattering phase shifts of two nucleons on a quantum computer. Given the prevalent noise in current-era Noisy Intermediate-Scale Quantum (NISQ) hardware, noise-resilient quantum algorithms become crucial. We employ two such algorithms: the Variational Quantum Eigensolver (VQE) and the Quantum Subspace Expansion (QSE) to compute the phase shifts in the deuteron $^3S_1$ partial wave. Additionally, I will elaborate on the noise mitigation techniques we implemented and discuss the further noise mitigation required to conduct this calculation on a higher number of qubits.

Madhava Syamlal	QubitSolve

COMPUTATIONAL FLUID DYNAMICS ON QUANTUM COMPUTERS

QubitSolve is developing a quantum solution for computational fluid dynamics(CFD). We have developed a variational quantum CFD (VQCFD) algorithm and implemented it in a software prototype. We ran a sample of VQCFD circuits on IonQ and IBM quantum computers and collected performance data. Based on the data, we developed a VQCFD performance model. We also developed a performance model for classical CFD. This presentation discusses the development of the performance models and compares VQCFD and classical CFD performance.

Himanshu Thapliyal	University of Tennessee-Knoxville

APPROXIMATE COMPUTING FOR NOISE RESILIENT RESOURCE OPTIMIZED QUANTUM CIRCUITS

Approximate computing is a novel computing paradigm that produces imprecise results by relaxing the need for fully precise or completely deterministic operations; such error-tolerant applications include multimedia, data mining, and image processing. Approximate computing often utilizes statistical properties of data and algorithms to trade away quality for improvements in other figures of merit (such as energy, area, and power reduction in classical computing). In quantum computing, approximate computing can trade circuit accuracy to optimize other parameters such as noise fidelity, quantum depth, and resource utilization. This approach is particularly useful in applications domains of quantum computing where exact results are not required, such as machine learning, signal processing, and image processing. This talk will discuss the approximate quantum arithmetic circuits that serve as the building blocks for complex applications. Also, we will discuss the progress towards a design automation tool that can produce approximate quantum circuits that can achieve higher accuracy than the baseline exact circuits.

Elaine Wong	Oak Ridge National Laboratory

A CROSS-PLATFORM QIR EXECUTION ENGINE

We introduce the Quantum Intermediate Representation (QIR) Execution Engine (QIR-EE), marking a practical advancement in quantum computational science, effectively bridging quantum and classical computing by interpreting and executing the hybrid language format specified by the QIR. This execution engine supports a wide range of quantum instructions and manages quantum results, essential for those working with quantum algorithms. By processing QIR, the QIR-EE makes it easier to work across different platforms. Notably, QIR-EE provides extension points for different runtime and hardware accelerators and includes an implementation that adapts those interfaces to the eXtreme-scale ACCelerator (XACC) front end to dispatch to a variety of simulators and quantum hardware. In this talk, we will present the QIR-EE architecture and explain how it handles quantum instructions, manages results, and integrates with existing quantum computing frameworks. We use QIR-EE to demonstrate end-to-end simulator/hardware-agnostic execution of several prototypical programs. Furthermore, we can report that through ORNL,Äôs QCUP program, we show how we validate execution with QIR-EE on a variety of backends, including IonQ,Äôs qpu.harmony simulator and hardware, Quantinuum,Äôs H1-1E emulator. These results highlight QIR-EE,Äôs use for hybrid applications and shows a way forward in the complex landscape of quantum computing, presenting a pragmatic approach that could help many in the field.

3. POSTERS

Esam El-Araby	University of Kansas

EFFICIENT MULTIDIMENSIONAL QUANTUM CONVOLUTIONAL CLASSIFICATION

In this work, we present a multidimensional quantum convolutional classifier (MQCC) that performs multidimensional and multifeature quantum convolution with average and Euclidean pooling, thus adapting the CNN structure to a variational quantum algorithm (VQA). The experimental work was conducted using multidimensional data to validate the correctness and demonstrate the scalability of the proposed method utilizing both noisy and noise-free quantum simulations. We evaluated the MQCC model with reference to reported work on state-of-the-art quantum simulators from IBM Quantum and Xanadu using a variety of standard ML datasets. The experimental results show the favorable characteristics of our proposed techniques compared with existing work with respect to a number of quantitative metrics, such as the number of training parameters, cross-entropy loss, classification accuracy, circuit depth, and quantum gate count.

Eyal Bairey	Qedma Quantum Computing

QESEM: ERROR SUPPRESSION AND MITIGATION PRODUCT FOR QUANTUM COMPUTING

As we approach utility-scale quantum computations which cannot be verified classically, solutions for cancelling noise with guaranteed accuracy are becoming increasingly important. Qedma's Error Suppression and Error Mitigation product "QESEM" is a one-stop-shop for eliminating noise in quantum circuits, enabling users to obtain guaranteed error-free results on circuits of unrivaled complexities using today's quantum hardware. We show demonstrations of QESEM on various quantum algorithms and hardware platforms, including recent results on an IBM Eagle device exhibiting the largest amount of noise mitigated in a utility-scale experiment.

Hermanni Heimonen	IQM Quantum Computers

RECENT TECHNOLOGY DEVELOPMENTS AT IQM

In the last year, IQM has reached several technology breakthroughs highlighted here. These include 1ms lifetimes of transmon qubits, 99.9% fidelity CZ gates using the IQM tunable coupler, and generating genuine many-body entanglement across entire quantum computers. These technologies are now being implemented in our commercial offering of cloud and on-premises superconducting quantum computers. Currently available systems with technical specifications are shown as well.

Sounak Bhowmik	University of Tennessee-Knoxville

TRANSFER LEARNING BASED HYBRID QUANTUM NEURAL NETWORKS FOR CLASSIFICATION

The rapid increase in the volume of data increases the challenges in managing, processing, and analyzing this data. My research focuses on leveraging quantum computing to develop efficient algorithms for large-scale data processing, aiming to improve computational speed and accuracy.

Junghoon Chae	Oak Ridge National Laboratory

VISUAL ANALYTICS OF PERFORMANCE OF QUANTUM COMPUTING SYSTEMS AND CIRCUIT OPTIMIZATION

Driven by potential exponential speedups in business, security, and scientific scenarios, interest in quantum computing is surging. This interest feeds the development of quantum computing hardware, but several challenges arise in optimizing application performance for hardware metrics (e.g., qubit coherence and gate fidelity). In this work, we describe a visual analytics approach for analyzing the performance properties of quantum devices and quantum circuit optimization. Our approach allows users to explore spatial and temporal patterns in quantum device performance data and it computes similarities and variances in key performance metrics. Detailed analysis of the error properties characterizing individual qubits is also supported. We also describe a method for visualizing the optimization of quantum circuits. The resulting visualization tool allows researchers to design more efficient quantum algorithms and applications by increasing the interpretability of quantum computations.

Srikar Chundury	North Carolina State University

QUANTUM FRAMEWORK WITH NWQ-SIM AND TN-QVM

In the foreseeable future, quantum computing (QC) could potentially revolutionize several fields by providing exponential speedups over classical counterparts. This research explores QC algorithms for combinatorial optimization problems, aiming to address their practical implementations and limitations.

Matthew DeCross	Quantinuum

THE COMPUTATIONAL POWER OF RANDOM QUANTUM CIRCUITS IN ARBITRARY GEOMETRIES

We describe recent hardware upgrades to Quantinuum's H2 quantum computer enabling it to operate on up to 56 qubits with arbitrary connectivity and high two-qubit gate fidelity. Utilizing the flexible connectivity of H2, we present data from random circuit sampling in highly connected geometries, doing so at unprecedented fidelities and a scale that appears to be beyond the capabilities of state-of-the-art classical algorithms. The considerable difficulty of classically simulating H2 is likely limited only by qubit number, demonstrating the promise and scalability of the QCCD architecture as continued progress is made towards building larger machines.

Yuhua Duan	National Energy Technology Laboratory

OVERVIEW OF NETL QUANTUM FOR ENERGY SYSTEMS AND TECHNOLOGIES (QUEST)

NETL QUEST focuses on applying quantum information science (QIS) to energy technologies, particularly in optimizing material properties for energy storage and conversion. This project seeks to develop QIS-based models and simulations to predict material behaviors under various conditions.

Bhaskar Gaur	University of Tennessee

RESIDUE NUMBER SYSTEM (RNS) BASED DISTRIBUTED ARITHMETIC FOR QUANTUM COMPUTING

Quantum Arithmetic faces limitations such as noise sensitivity and resource inefficiency. This research aims to develop robust quantum arithmetic circuits by leveraging error correction techniques and optimizing resource allocation, improving overall computational reliability.

Qiang Guan	Kent State University

ENHANCING THE USABILITY OF QUANTUM INFRASTRUCTURE THROUGH INNOVATIVE ALGORITHMS

In this project, we propose developing innovative quantum algorithms for solving large-scale optimization problems in logistics and supply chain management. Our approach focuses on enhancing algorithmic efficiency and ensuring practical applicability in real-world scenarios.

Arijit Gupta	National High Magnetic Field Laboratory

DETECTION AND CONTROL OF QUANTUM SPINS IN A DILUTED SPIN ENSEMBLE VIA ON-CHIP SUPERCONDUCTING RESONATOR

Rare-earth ion spins diluted in non-magnetic crystals have shown great potential for physically realizing qubits due to their long coherence times. This research aims to study the strong coupling of the spin ensemble with the electromagnetic mode of an on-chip superconducting resonator.

Clemente Guzman	National High Magnetic Field Laboratory

OPTIMIZATION AND PRELIMINARY RESULTS ON COMBINED QUANTUM COMPUTING AND HIGH-PERFORMANCE COMPUTING (QC-HPC)

Large-scale, universal quantum computers are still in their infancy. This project focuses on advancing the development of spin-based qubits via superconducting quantum interference devices (SQUIDs) and RF cavity resonators, aiming to fabricate on-chip devices capable of sensitive spin detection and quantum state manipulation.

Max Haeberlein	IQM Quantum Computers

IQM RESONANCE - A QUANTUM CLOUD PLATFORM FOR PROFESSIONAL USERS

In this poster, we will describe IQM Resonance functionalities, IQM's quantum computer products, and produce an outlook for future developments.

Nils Herrmann	Quantum Brilliance

QML-BOOSTED OPTIMIZATION ALGORITHMS FOR NEAR-TERM QUANTUM COMPUTERS

Quantum computing has long promised transformational changes in various fields, yet achieving practical quantum advantage remains a challenge. This research explores the development of room-temperature quantum accelerators, aiming to make quantum computing more accessible and practical.

David Joy	Oak Ridge National Laboratory

NOVEL QUANTUM GENETIC ALGORITHM FOR BETTER CLASSICAL PERFORMANCE

We create a circuit to perform one-point crossover on two strings of 4 qubits using IBM's Qiskit. We benchmark our implementation against classical genetic algorithms, aiming to demonstrate the feasibility of quantum genetic algorithms for evolutionary computation.

Waseem Kamleh	Quantum Brilliance

THE QUANTUM BRILLIANCE SDK

Quantum Brilliance offers a full stack SDK for developing applications on their room-temperature quantum accelerators. This project focuses on optimizing quantum algorithms for specific use cases, aiming to demonstrate practical quantum advantage in industrial applications.

Zoha Laraib	University of Tennessee-Knoxville

MANY-BODY NEUTRINO FAST FLAVOR CONVERSIONS IN THE PRESENCE OF TURBULENT FIELDS

The flavor transformation of neutrinos through coherent elastic neutrino-nucleus scattering (CEvNS) provides a promising approach for detecting and studying neutrino properties. This research aims to develop quantum-enhanced detection techniques to improve measurement precision.

Vincente Leyton Ortega	Oak Ridge National Laboratory

AUTOMATIC QUANTUM CIRCUIT GENERATOR: LEVERAGING GENETIC STRATEGIES AND HYBRID CLASSICAL-QUANTUM COMPUTING

Quantum computing could advance basic science with software that automatically generates quantum circuits to compute the ground state of a given Hamiltonian. Our free and open-source software development [code.ornl.gov/gonzalo_3/evendim] already accomplishes this, but it is not yet efficient. This poster will discuss the roadmap to achieving efficiency and the potential roadblocks. To make this work, we need to penalize or discard deep layered circuits, and we will examine the impact on convergence. The need for high-performance (classical) computing and the benefits of hybrid computing, where quantum circuit fitness can be evaluated on quantum hardware, will also be addressed. We are adapting this methodology and developing software to execute our algorithm on large scale HPC cluster including the Summit supercomputer at ORNL, utilizing XACC with various accelerators. This strategy can be extended to solving combinatorial problems using quantum computers. Fields such as condensed matter, computational chemistry, and high-energy physics should benefit from this approach, as our generator provides insightful, non-intuitive quantum circuits that could not have been designed manually.

Jinyang Li	George Mason University

A NOVEL SPATIAL-TEMPORAL VARIATIONAL QUANTUM CIRCUIT FOR TIME SERIES PREDICTION

Quantum computing presents a promising approach for solving computationally intensive problems in various fields. This research explores the development of quantum algorithms for machine learning applications, aiming to improve the efficiency and accuracy of data-driven models.

Xiuwen Liu	Florida State University

REALIZING AN EFFECTIVE TRAINING PROGRAM FOR A QUANTUM MACHINE LEARNING PIPELINE

The project is centered around realizing an effective training program for a diverse quantum proficient workforce development. By adding quantum proficiency to popular science majors, the main goal is to help address the lack of quantum workforce, which is recognized as a national vulnerability. Focusing on science majors overcomes the uncertainty of the size of the quantum industries as the implementation of secure applications and systems using post-quantum cryptography, quantum-key distributions, quantum networks, and quantum simulations will provide ample career opportunities. To appeal to science majors, the program will be designed based on an end-to-end problem-solving framework that will place quantum- and quantum-inspired solutions into proper contexts and foster developing genuine and in-depth understandings of advantages of quantum solutions, and grasping computational skills intuitively. The required courses and the supporting materials and activities will be designed and iteratively improved in the Social Cognitive Career Theory (SCCT) framework so that the effectiveness of the program components can be measured quantitatively using survey data and other observable outcomes (such as students' GPA, internship placement, and job placement). In particular, by developing programming skills of the students in the program and building on the team's deep understanding of cyber security and quantum education, the tailored questions and tutorials would provide an effective and time-efficient way for the students to learn quantum solutions.

Naveed Mahmud	Florida Institute of Technology

HYBRID QUANTUM-CLASSICAL MACHINE LEARNING APPROACHES FOR SENTIMENT ANALYSIS

The intersection between quantum computing and artificial intelligence presents new opportunities for developing advanced computational models. This research investigates the integration of quantum algorithms with neural networks, aiming to enhance their learning capabilities.Our focus is on developing an integrated framework of quantum-classical machine learning models for sentiment analysis of textual data, specifically targeting human emotions and opinions within large-scale datasets.

Edric Matwiejew	Pawsey Supercomputing Research Centre

SIMULATION-DRIVEN DEVELOPMENT OF QUANTUM VARIATIONAL ALGORITHMS WITH QUOP_MPI

QuOp_MPI is a framework for the design of quantum variational algorithms (QVA) by state vector simulation of their fundamental unitary dynamics. It expresses QVAs as continuous-time quantum walks to target efficient quantum processor usage. The Python interface with user-definable functions enables rapid prototyping and the GPU-enabled MPI-parallel backends ensures simulations can scale. Researchers have used it to explore QVAs applied to practical problems ranging from finance to astrophysics.

Karl Mayer	Quantinuum

BENCHMARKING LOGICAL QUANTUM FOURIER TRANSFORM ON THE QUANTINUUM H-SERIES HARDWARE

We implement logically encoded circuits for the 3-qubit quantum Fourier transform (QFT), using the 7-qubit Steane code, and execute the circuits on the Quantinuum system model H2-1. We first benchmark individual logical components using randomized benchmarking. We then implement two versions of the full QFT circuit, and lower bound the process fidelity. We compare the logical QFT benchmark results to predictions based on the logical component benchmarks.

Md. Saif Hassan Onim	University of Tennessee-Knoxville

PERFORMANCE OF QUANTUM HYBRID SUPPORT VECTOR MACHINES IN STRESS DETECTION

In this work, we address stress detection through quantum-enhanced machine learning techniques. Our approach leverages quantum algorithms to analyze physiological data, aiming to develop accurate and real-time stress detection models.

Srilakshmi Palanikumar	Howard University

QUANTUM FOURIER TRANSFORM FOR MAGNETIC RESONANCE IMAGING DATA RECONSTRUCTION

The Fourier transform decomposes a complex waveform into the frequencies that it comprises. The quantum Fourier transform (QFT) performs the same operation but provides a significant computational advantage by leveraging quantum parallelism. This enables an exponential speedup over the classical algorithm; whereas the time complexity of the classical Fourier transform is $O(N \log N)$, the quantum Fourier transform has a time complexity of $O(\text{log\^{}2 } N)$. Current magnetic resonance imaging (MRI) reconstruction techniques are computationally intensive, resulting in lengthy processing times. We analyzed noisy 3D MRI models of five different human pancreases, classically reconstructed from multiple 2D slices using PyVista in Python, and processed the data using the iterative closest point algorithm by registering four of the noisy models to a ground truth model. Future work will explore quantum speedups for this classical MRI image reconstruction, with a larger set of pancreases.

Ciaran Ryan-Anderson	Quantinuum

EXPERIMENTAL REALIZATION OF HIGH-FIDELITY AND FAULT-TOLERANT TELEPORTATION PROTOCOLS

Quantum state teleportation is commonly used in quantum communication protocols. This research experimentally realizes and explores different logical teleportation protocols for quantum error correction (QEC) including utilizing transversal gates and lattice surgery, obtaining relatively high fidelities.

Liwen Shih	University of Houston-Clear Lake

QA^HPC – QUANTUM AI ACCELERATED HPC

QA^HPC explores Quantum AI & HPC synergy for computation energy sustainability. Quantum optimization has been successfully demonstrated in many industrial logistic optimizations. We apply Quantum TSP solver to reorder computation for faster pipeline processing with higher memory hit ratio. Quantum Multiple Vehicle Routing is employed to automate latency-adaptive computation workflow graph thread partitioning & scheduling for customizing compact job-specific processor subnet topology with reduced user core-hour charge & time. Bin Packing & Graph Embedding will enhance topology-aware HPC cluster subnet allocation among user computation jobs to reduce network traffic and data hop movement for increasing HPC utilization & efficiency.

Goksu Toga	North Carolina State University

QUANTUM SIMULATING HYPERBOLIC ISING MODEL

In this poster, we will develop techniques for simulating the Hyperbolic Ising model which describes an Ising model that lives in a discretization of AdS2 using MPS/MPO and usual quantum simulation techniques. We will investigate the information propagation in this curved background and show evidence that this model scrambles information in a logarithmic fashion and hence can be classified as a fast scrambler.

Yan Wang	Oak Ridge National Laboratory

EFFICIENT DIRECT MEASUREMENT OF MERMIN POLYNOMIAL OPERATOR FOR QUANTUM ENTANGLEMENT

Entanglement is a fundamental resource of quantum computation and thus a universal metric of evaluating quantum utility of all quantum devices. Mermin polynomial operator can be used to operationally characterize quantum entanglement and verify quantum nonlocality. However, for general states without high symmetry like maximally entangled GHZ states, it requires measuring exponential number of Pauli string terms in the Mermin polynomial. By applying a symmetric form of linear combination of unitaries (LCU) to the recursive definition of Mermin polynomial of n-qubit system, we derive a novel algorithm to efficiently and directly measure Mermin polynomial. Our algorithm only uses O(n) depth circuits with O(n) mid-circuit measurements and the LCU encoding success probability is O(1) for GHZ states.