INQA Conference 2023

Quantum Annealing: New Platforms and Algorithms

Quantum Annealing is a computational method to solve combinatorial optimization and sampling problems. The INQA 2023 conference will cover various topics related to quantum annealing, focusing on new hardware platforms and novel optimization algorithms and their implementation. The conference aims to bring together leading researchers from academia and industry to share their latest findings and discuss future directions for quantum annealing research. Therefore, contributions within this theme or in any other related area of quantum annealing research are welcome. The event is a sequel to the INQA conference 2022 (London).

Members of the INQA management board who helped organise this conference along with the INQA seminar series include:

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- Dr Pol Forn-Díaz (IFAE, Spain)
- Dr Shiro Kawabata (AIST, Japan)
- Prof Viv Kendon (University of Strathclyde, UK)
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INQA is supported by an International Network Grant from the UK Engineering and Physical Sciences Research Council.

Venue

Ceremonial Hall of the University of Innsbruck

The University of Innsbruck was one of the pioneers of quantum computing and now hosts a critical mass of quantum computing scientists. As quantum computing moves from fundamental and academic research toward industrial applications, Innsbruck aims to continue playing a pivotal role. The 2nd International Network on Quantum Annealing conference will take place at the ceremonial hall of the University of Innsbruck.

Address:

University of Innsbruck
Innrain 52
6020 Innsbruck

Programme

Monday 6 November 2023

Welcome | Paul Warburton, UCL

9:00 - 9:15

Session 1

9:15 - 10:00

Superconductor Digital Circuits: Recent Progress and Quantum Applications | Naoki Takeuchi, AIST, Japan

Superconductor digital circuits can operate with very low power dissipation at cryogenic temperatures and are thus promising building blocks for quantum-bit (qubit) interface circuits. In this study, we give a talk on recent progress and possible quantum applications of superconductor digital circuits. Specifically, we show qubit interface circuits using an ultra-low-power superconductor logic, namely adiabatic quantum-flux-parametron logic.

Session 2

10:00 - 10:45

Characterising and benchmarking quantum platforms: The challenge, the state of play and the future outlook | Jessica Park, DSTL, UK

Quantum Computing (QC) is still in relative infancy with a high rate of development, investment and research being devoted to its improvement. However, there is little consensus in the industry and wider literature as to what improvement might consist of beyond ambiguous statements of “more qubits” and “less error”. Before one can decide how to improve something, it is first necessary to define the criteria for success: i.e. what are the metrics or statistics that are relevant to the problem? The lack of clarity surrounding this question and its potential answers has led to a rapidly developing capability with little consistency and standards present across the board. This talk will present a review of the current state of play regarding both application-driven and application agnostic benchmarks, before then exploring some of the methodology developed and results obtained by the authors when looking at characterising and benchmarking quantum annealing platforms.

Coffee break

10:45 - 11:15

Session 3

11:15 - 11:40

A strategy exploiting coherence for diabatic quantum annealing | Werner, Matthias Qilimanjaro Quantum Tech / University of Barcelona, Spain

In recent years there have been great advances in improving the coherence of quantum annealing hardware. First experiments show the presence of coherence in large devices, sparking hopes for quantum advantage through quantum annealers. However, it is an open question how quantum annealers can exploit coherence to successfully solve computational problems. Here, we propose an explanation for the utility of a particular coherent effect. We discuss how the interference between amplitudes of different energy levels after consecutive Landau-Zener crossings, also known as Landau-Zener-Stückelberg (LZS) interference, can be used to solve and, in some cases, speed-up the preparation of the ground state of a target Hamiltonian. Based on our previous work on first-order quantum phase transitions (QPT), we propose and numerically investigate a mechanism that uses LZS interference to populate the first excited state, which in turn allows to avoid slow tunneling at the first-order QPT. Our analysis of a working principle of diabatic schedules provides an intriguing and intuitive physical explanation of potential advantages of diabatic quantum annealing over its adiabatic counter-part. Ultimately, our results pave the way towards designing algorithms that explicitly utilize LZS interference in diabatic quantum annealing.

Session 4

11:40 - 12:05

Beyond-Kibble-Zurek physics in the transverse-field Ising model | Federico Balducci, University of Luxembourg, Luxembourg

Crossing a quantum phase transition in finite time leads to the formation of excitations, such as topological defects, since the dynamics necessarily fails to be adiabatic near the transition point. The average number of excitations is well described by the celebrated Kibble-Zurek (KZ) mechanism, predicting a universal scaling law with the quench time. Recently, the scope of the KZ paradigm has been expanded, enabling the prediction of quantities beyond averages, such as the full counting statistics of defects. In this talk, I will present some results that clarify the role of universality in beyond-KZ physics, using the paradigmatic example of the transverse-field Ising model. I will show how the exact solution of the model allows to distinguish between universal and non-universal features in the kink distribution, and elucidate their dependence on the quench time. I will finally argue how these theoretical predictions are already testable in current quantum simulators and annealers.

REF: FB, M. Beau, J. Yang, A. Gambassi, A. del Campo, arXiv:2307.02524

Session 5

12:05 - 12:50

Excited states in the quantum annealing | Takashi Imoto, AIST, Japan

Quantum annealing was proposed as a method to find the ground state of a desired Hamiltonian through adiabatic time evolution. Various applications of quantum annealing have been proposed, including combinatorial optimization problems, machine learning, quantum chemical calculations, and cryptanalysis. More recently, quantum annealing using excited states has also been proposed. In this talk, we will elucidate our findings pertaining to adiabatic quantum computation utilizing excited states.

Lunch

12:50 - 14:15

Session 6

14:15 - 15:00

How it Goes: Reconciling Different Views of Quantum Annealing Performance | Catherine McGeoch, D-Wave, Canada

Several approaches to evaluating performance of quantum systems have been proposed. As a general rule, these proposals are incompatible in the sense that a demonstration of superior quantum performance in one context does not imply that superior quantum performance will be observed in others. The talk will survey the current status of current-generation Advantage systems from these different points of view, and will venture some predictions about performance of Advantage2 systems due to be released in 2023/2024.

Session 7

15:00 - 15:45

Direct observation and manipulation of quantum interference in a superconducting Kerr parametric oscillator | Jaw-Shen Tsai, RIKEN, Japan

Quantum tunneling is the phenomenon that makes superconducting circuits “quantum”. We report a direct observation of quantum interference induced by such tunneling and its dynamics in a planar superconducting circuit through Wigner tomography. We experimentally elucidate all essential properties of this quantum interference, such as mapping from Fock states to cat states, a temporal oscillation due to the pump detuning, as well as its characteristic Rabi oscillations and Ramsey fringes. Finally, we perform gate operations as manipulations of the observed quantum interference.

Coffee break

15:45 - 16:15

Session 8

16:15 - 17:00

Accelerating equilibrium spin-glass simulations using quantum annealers via generative deep learning | Sebastiano Pilati, UNICAM, INFN, Italy

Simulating the equilibrium properties of spin glasses is a notoriously hard computational task. It plays a key role in condensed matter physics, and it is also relevant for the solution of combinatorial optimization problems.
In this talk I will discuss how to accelerate Monte Carlo simulations of spin glasses using autoregressive neural networks trained on configurations generated by a D-WAVE quantum annealer. One obtains an impressive suppression of the long correlation times that plague low-temperature simulations. Hybrid algorithms that combine neural and single-spin flip updates will also be discussed, as well as the data augmentation with data produced via classical simulations. We obtain performances comparable or superior to those of parallel-tempering algorithms.
Notably, the hybrid algorithm is able to frequently sample ground-state configurations, even when these are not present in the training dataset.
If time permits, I will also discuss how a quantum-annealing-inspired parameter-initialization allows one to drastically ameliorate the computational scaling of gate-based optimization algorithms, such as QAOA, which turn out to be plagued by an impractical scaling when measurement shot noise is properly considered.

G. Scriva, E. Costa, B. McNaughton, S. Pilati, SciPost Phys. 15, 018 (2023)

Session 9

17:00 - 17:45

Quantum annealing with Kerr parametric oscillators, Josephson parametric oscillators, and the Lechner-Hauke-Zoller scheme | Ryoji Miyazaki, NEC, Japan

The advent of programmable quantum annealers has been inspiring the realm of quantum annealing and leading to many theoretical, experimental, and industrial progress. More than a decade has passed since then, and it is a time to expect to see new quantum annealers based on the progress. NEC is developing a new quantum annealer with a different model, qubit platform, and encoding scheme than existed ones.
Our model of quantum annealing is described with Kerr parametric oscillators (KPOs) [1], which seems to be distinctly different from the conventional one, i.e., the transverse-field Ising model. We gradually increase the pump amplitude for the parametric driving, and a KPO finally lies on a cat state in which an Ising spin is encoded. KPOs can be generated as qubits implemented with Josephson parametric oscillators (JPOs) [2], which consist of superconducting circuits with SQUIDs threaded by modulated magnetic fluxes. Qubits of JPOs also play a role of a bridge to an encoding method, the Lechner-Hauke-Zoller (LHZ) scheme [3], where a product of logical qubits is encoded in a physical qubit. The LHZ scheme does not require interactions between distant physical qubits, but the interactions involve four-body couplings, which are difficult to be implemented. We can overcome this

difficulty with JPOs. Superconducting circuits with JPOs have been theoretically proposed to realize the four-body interaction [4].
In this talk we discuss the above scenario of a new quantum annealer with KPOs, JPOs, and the LHZ scheme. The scenario relies on recently proposed ideas, and it raises several questions to be resolved. The second half of the talk addresses two theoretical problems among them. One is how quantum annealing with KPOs is described with spin models [5]. This is the first step to compare the method with the conventional one. The other is how we increase the four-body coupling constant of JPOs. This concerns the central issue to implement the LHZ scheme with JPOs. We also report experimental developments in NEC to realize the quantum annealer [6].
This work is based on results obtained from a project, JPNP16007, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

[1] H. Goto, Sci. Rep. 6, 21686 (2016).
[2] Z. Wang, et al., Phys. Rev. X 9, 021049 (2019).
[3] W. Lechner, P. Hauke, and P. Zoller, Sci. Adv. 1, e1500838 (2015).
[4] S. Puri, C. K. Andersen, A. L. Grimsmo, and A. Blais, Nat. Commun. 8, 15785 (2017).
[5] R. Miyazaki, Phys. Rev. A 105, 062457 (2022).
[6] T. Yamaji, et al., Phys. Rev. A 105, 023519 (2022); T. Yamaji, et al., Phys. Rev. Applied 20, 014057 (2023).

Social dinner

Tuesday 7 November 2023

Session 1

9:00 - 9:45

Quantum Optimization with Rydberg Atom Arrays | Hannes Pichler, Innsbruck University, Austria

Individually trapped neutral atom arrays have unique features for realizing various tasks ranging from quantum simulation to quantum information processing. They include easy scalability, strong coherent interaction via excitation to Rydberg states, and high degree of programmability. In this talk I will discuss how these properties can be exploited to implement and test quantum optimization algorithms for classical combinatorial optimization problems. In particular I will focus on the maximum independent set problem whose cost function has a natural realization in Rydberg atom arrays on certain classes of graphs. I will discuss various classical encoding strategies based on unit-disk encoding gadgets, and comment on their quantum properties.

Session 2

9:45 - 10:30

Algorithms and applications on Aquila: QuEra's cloud-accessible analog Hamiltonian simulator based on programmable Rydberg atom arrays | Alexei Bylinskii, QuEra USA

Aquila is the world's only publicly accessible neutral-atom quantum computer sporting up to 256 qubits arranged in programmable arrays and global control of the Rydberg interactions between them. I will start with how Aquila works under the hood and describe its capabilities accessible to you via the cloud. I will then present two scientific studies conducted on Aquila: one highlighting a paradigmatic application of the system, and one highlighting its algorithmic flexibility. The first one demonstrates the creation of a novel critical phase exhibiting incommensurate order using a standard quantum adiabatic protocol. The second one demonstrates the power of a diabatic protocol based on many-body quench dynamics, judiciously placed within a quantum adiabatic protocol, to circumvent the adiabatic gap problem in preparing maximally difficult quantum many-body ground states.

Coffee break

10:30 - 11:00

Session 3

11:00 - 11:25

Formulating Structural Design Optimization Problems for Quantum Annealing | Fabian Key, TU Wien, Austria

We investigate a formulation of structural design optimization problems, which aims to be solved by quantum annealing (QA) on currently available devices. In structural design optimization, the goal is to improve the performance and efficiency of structures by finding the best design, e.g., a choice of component dimensions, that meets specific criteria, such as maximizing strength. This process typically involves computational optimization methods to explore various design possibilities. Here, a recently evolving strategy based on quantum mechanical effects is QA. In this context, a suitable problem needs to be provided in a specific formulation, e.g., as quadratic unconstrained binary optimization (QUBO) model. Therefore, we present a corresponding formulation for structural design optimization problems. In such a problem, an analysis model is required to evaluate the structure's performance. For this purpose, we use energy minimization principles to determine how a structure behaves under applied loads. This allows us to merge the analysis problem with the optimization problem as one overall minimization problem. Finally, mapping this problem to a QUBO problem enables us to solve it with QA.
We apply this approach to a sizing problem of a one-dimensional compound bar under self-weight loading. In this course, we study how specific aspects of the formulation influence the number of required qubits. The accuracy of the obtained results is evaluated by means of analytic solutions. In conclusion, we show that the presented formulation can be used to solve structural design optimization problems by QA on existing hardware.

Session 4

11:25 - 11:50

Guided Quantum Walk | Willsch Dennis, Forschungszentrum Jülich, Germany

We introduce the guided quantum walk (GQW) as a new algorithm that interpolates between quantum walk (QW) and quantum annealing (QA), extending the concept of multi-stage continuous-time QWs. The GQW is based on insights from the theory of local amplitude transfer, which sheds new light on the working principles of QA beyond the adiabatic theorem. We assess the performance of the GQW on exact cover, traveling salesperson and garden optimization problems with up to 30 qubits. Our results provide evidence for the existence of optimal annealing schedules, capable of solving problems within evolution times that scale only linearly in the problem size. We resolve this apparent paradox by considering a new metric that correctly accounts for the cost of the classical optimization phase.

Session 5

11:50 - 12:35

Beyond MIS: Performing analogue optimisation on a neutral atom array using local addressing | Jonathan Pritchard, Strathclyde, UK

Neutral atoms have emerged as a powerful and scalable platform for quantum computing, offering the ability to generate large numbers of identical and high quality qubits in reconfigurable arrays. By coupling atoms to highly excited Rydberg states with strong, long-range dipole-dipole interactions this system can natively implement maximum independent set (MIS) on a unit disk graph, providing a route to performing analogue optimisation of real problems. To go beyond MIS to a broader class of graph problems, it is necessary to implement local addressing to perform site-dependent Stark shifts. In this talk we present work to develop a large-scale system for quantum computing and annealing, and show preliminary results highlighting our ability to apply controllable light-shifts across the atom array to implement simple demonstrations of weighted graph optimisation.

Lunch and poster session (part 1)

12:35 - 14:00

Poster session (part 2)

14:00 - 15:20

Session 6

15:20 - 16:05

Parent Hamiltonian reconstruction via inverse quantum annealing | Davide Rattacaso, University of Padua, Italy

Finding a local Hamiltonian with a specific many-body wave function as its ground state poses a substantial computational challenge. Solving this challenge can have a profound impact on advancing quantum technologies, ranging from benchmarking quantum devices to facilitating quantum state preparation. We present a novel method, inspired by quantum annealing, designed to address this task through artificial inverse dynamics. By slowly deforming the state, we induce an adiabatic evolution of the corresponding Hamiltonian. We name this approach "inverse quantum annealing" (IQA). In cases where long-range correlations are absent, the Hamiltonian generated through adiabatic evolution well approximated a solution for our inverse problem. Notably, IQA allows for an efficient numerical implementation, relying solely on the knowledge of local expectation values. To validate our approach, we apply inverse quantum annealing to discover a local Hamiltonian for two paradigmatic models and various system sizes. This exploration also allows us to investigate the effects of long-range correlations and traversing different-order phase transitions.

Coffee break

16:05 - 16:35

Session 7

16:35 - 17:20

Encoding Constrained Optimization Problems using the Parity Architecture | Wolfgang Lechner, Innsbruck/ParityQC, Austria

Constraints make hard optimization problems even harder to solve on quantum devices because they are implemented with large energy penalties and additional qubit overhead. The parity mapping, which has been introduced as an alternative to the spin encoding, translates the problem to a representation using only parity variables that encodes products of spin variables. In combining exchange interaction and single spin flip terms in the parity representation, constraints on sums and products of arbitrary k-body terms can be implemented without additional overhead in two-dimensional quantum systems.

Session 8

17:20 - 17:45 Virtual mitigation of coherent non-adiabatic transitions by echo verification | Dyon van Vreumingen, Universiteit van Amsterdam / CWI, Netherlands

Transitions out of the ground space limit the performance of quantum adiabatic algorithms, while hardware imperfections impose stringent limitations on the circuit depth.
We propose an adiabatic echo verification protocol which mitigates both coherent and incoherent errors, arising from non-adiabatic transitions and hardware noise, respectively.
Quasi-adiabatically evolving forward and backward allows for an echo-verified measurement of any observable.
In addition to mitigating hardware noise, our method uses positive-time dynamics only.
Crucially, the estimator bias of the observable is reduced when compared to standard adiabatic preparation, achieving up to a quadratic, and in some cases a quartic, improvement.

Wednesday 8 November 2023

Session 1

9:00 - 9:45

Effectiveness of quantum annealing for continuous-variable optimization | Hidetoshi Nishimori, Titech, Japan

We test the performance of quantum annealing (QA) applied to a one-dimensional continuous-variable function with a rugged energy landscape. After domain-wall encoding to map a continuous variable to discrete Ising variables, we first benchmark the performance of the D-Wave 2000Q against several state-of-the-art classical optimization algorithms designed for continuous-variable problems to find that the D-Wave 2000Q matches the classical algorithms in a limited domain of computation time. Beyond this domain, classical global optimization algorithms outperform the quantum device. Next, we examine several optimization algorithms that are applicable to the Ising formulation of the problem, such as the time-evolving block decimation (TEBD) to simulate ideal coherent quantum annealing, SA, SQA, and SVMC. The data show that TEBD's coherent quantum annealing achieves far better results than the other approaches, demonstrating the effectiveness of coherent tunneling. From these two types of benchmarks, we conclude that QA has the potential to outperform the best classical algorithms if thermal noise and other imperfections in the hardware are sufficiently suppressed and the device operates coherently, as demonstrated in recent short-time quantum simulations.urpass classical algorithms if hardware imperfections, like thermal noise, are minimized.

[1] S. Arai, H. Oshiyama, and H. Nishimori, arXiv:2305.06631

Session 2

9:45 - 10:30

Implementation of a modular architecture for generalized flux qubits | Ioan Pop, KIT, Germany

Up-scaling quantum processors while maintaining quantum coherence and local control is a daunting challenge. I will present a modular architecture for generalized flux qubits in which each element (qubit or coupler) has its dedicated chip and microwave enclosure. Each enclosure can host a readout&drive port, a fast flux port and a global magnetic field coil. The processor can be assembled by overlapping chiplets, which can be individually optimized. I will discuss current limitations and prospects for improvement.

Coffee break

10:30 - 11:00

Session 3

11:00 - 11:25

A general method to construct mean field counter diabatic driving for quantum annealing | Hiroshi Hayasaka, AIST, Japan

Quantum annealing (QA) has been attracted much attention as a method for searching a ground state of quantum many-body systems [1]. Generally, QA requires sufficiently slow dynamics to satisfy adiabatic conditions. On the other hand, the counter-diabatic (CD) driving is known to suppress non-adiabatic transitions and enables fast quantum annealing [2, 3]. However, constructing the CD term requires obtaining the exact eigenstates through classical computation in advance, and due to the non-local nature of the CD term, experimental implementation poses challenges.
As a solution to this issue, a method to approximate the CD term using a mean field (MF) approach was proposed [4]. In MF theory, for the case of a uniformly coupled ferromagnetic Ising model, the self-consistent equations to be solved reduce to a closed equation for the magnetization.
However, in cases where interactions are non-uniform, especially for problems with random interactions, such a spin glass, it is necessary to distinguish the magnetizations for each qubit. Consequently, the self-consistent equations become a set of N-nonlinear simultaneous equations, where N is the number of the qubit. As the construction of the MFCD term requires solving these self-consistent equations at each time step of quantum annealing, it becomes a bottleneck of computational time.
In this study, we propose a general and practical method to obtain the MF approximated CD term by using the MF dynamics of magnetization. In our approach, there is no need to solve the self-consistent equations at each time step, and only the initial configuration needs to be provided. We numerically demonstrate that the dynamics with the MF approximated CD term reproduces the self-consistent solution. Using this method, we perform QA for quantum spin glass and demonstrate that the ground state with high fidelity can be obtained compared to the conventional QA. Furthermore, we experimentally demonstrate our method by using a D-wave quantum annealer, Advantage, and obtain the experimental result supporting our numerical simulation. [5]. This paper was based on results obtained from a project, JPNP16007, commissioned by the New Energy and Industrial Technology Development Organization (NEDO), Japan.
[1] T. Kadowaki, et al., Phys. Rev. E, 58, 5355 (1998)
[2] M. Demirplak, et al., J. Phys. Chem. A 107, 9937 (2003)
[3] M. V. Berry, J. Phys. A: Mathematical and Theoretical 42, 365303 (2009)
[4] T. Hatomura, J. Phys. Soc. Jpn. 86, 094002 (2017)
[5] H. Hayasaka, et al., arXiv: 2305.08352

Session 4

11:25 - 11:50

Many-body localization detection based on quantum dynamics | Kazue Kudo, Ochanomizu University, Japan

MBL occurs in a strongly-disordered quantum many-body system. Typical methods to probe MBL are calculated using eigenenergy and eigenstates. Recently, techniques to probe MBL using quantum devices, e.g., a quantum annealer, have been developed, which take advantage of quantum dynamics. Instead of computing eigenstates, those techniques detect localization by measuring spins after time evolution. In this work, the disorder-induced localization is detected by evaluating the magnetization and a quantity called twist overlap at the end of time evolution. We discuss how the magnetization and twist overlap characteristics change between the thermal and localized phases. Numerical results suggest that the twist overlap after time evolution can work as a probe of MBL.

Session 5

11:50 - 12:35 Variational quantum simulation with trapped ions | Christian Roos, Innsbruck University, Austria

Laser-manipulated trapped ions constitute a quantum system that enable the realization of qubits and high-fidelity quantum operations with applications in quantum computing and simulation and precision spectroscopy. In this talk, I will discuss recent experiments with one- and two-dimensional ion crystals of 50-100 ions [1,2] that can be made to interact via a long-range Ising interaction. Applying this interaction in conjunction with single-qubit gates enables the realization of a family of variational quantum states that can be used for investigating the property of low-energy quantum states of a Hamiltonian [3] as well as the creation of spin-squeezed states [4] with application in quantum metrology.

[1] F. Kranzl et al, Phys. Rev. A 105, 052426 (2022)
[2] D. Kiesenhofer et al, PRX Quantum 4, 020317 (2023)
[3] M. K. Joshi, C. Kokail, R. van Bijnen et al, arxiv: 2306.00057, Nature (accepted)
[4] J. Franke et al., Nature 621, 740 (2023)

Lunch

12:35 - 14:00

Session 6

14:00 - 14:45

Iterative Quantum Algorithms and Quantum Annealing | Lucas Brady, NASA United States

Combinatorial Optimization problems have received a lot of focus as an area for potential quantum speedup and advantage through both adiabatic and variational algorithms. Despite this promise and attention, the prospects for quantum optimization on near-term hardware remain murky with circuits that are too short for fully adiabatic processes or requiring too many variational parameters to feasibly optimize effectively. To address this we formalize notions of Iterative Quantum Algorithms which seek to use the classical co-processor in new ways. This iterative framework can work with a wide variety of quantum and classical sub-components, from quantum annealing to classical Monte Carlo. We explore the scope and breadth of this algorithmic design philosophy and demonstrate it in several settings and modes. As highlights, we show that these methods perform similarly to classical greedy algorithms for Maximum Independent Set and demonstrate an expansion of branch-and-bound methods to quantum hybrid algorithms.

Session 7

14:45 - 15:30

Quantum search and optimization with quantum walks | Leonardo Novo, International Iberian Nanotechnology Laboratory, Portugal

Quantum walks, the quantum analogue of classical random walks, became an important framework for the development of quantum algorithms. In this talk, I will show how some analytical results about the performance of quantum walk search algorithms can be used to analyze quantum algorithms for finding minima of cost functions via an adiabatic unstructured search approach. In order to obtain the expected Grover-like speed-up with the latter approach, it is necessary to have a precise knowledge of the position of the avoided crossing. However, we show that determining this exactly is a #P-HARD problem. This raises the question of whether a provable quadratic speed-up over classical unstructured search can be obtained for optimization problems in the adiabatic setting. Finally, I will discuss quantum walk inspired approaches to solve optimization problems requiring low coherence times, showing analytical and numerical evidence that they may outperform QAOA.

Coffee break

15:30 - 16:00

Session 8

16:00 - 16:45

Classification problems for quantum machine learning: how should we ask questions to quantum computers? | Kae Nemoto, Okinawa Inst of Sci and Tech, Japan

There has been a huge world-wide effort to find problems which small-scale quantum computers (NISQ processors) can easily solve. However it turns out to be rather difficult to find practical problems NISQ processors are really good at. In this talk, we address this issue by asking ourselves a simple question: how should we ask questions to noisy quantum computers? We first introduce the quantum extreme reservoir computation (QERC) model, which can solve various classification problems with high accuracy using as few as 10 qubits. We go through the advantages and disadvantages of QERC and discuss hardware architectures suitable to realize this computational model.

Session 9

16:45 - 17:30

Simulating Heavy-Hex Transverse Field Ising Model Magnetization Dynamics Using Programmable Quantum Annealers | Elijah Pelofske, LANL, United States

Quantum computers are now in the regime where it is interesting to evaluate to what extent their computations can be exactly, or approximately, simulated on classical computers. Recently, a Hamiltonian dynamics simulation was performed on a kicked ferromagnetic 2D transverse field Ising model with a connectivity graph native to the

127 qubit heavy-hex IBM Quantum architecture, and using ZNE quantum error mitigation. We demonstrate that one of the observables in this Trotterized Hamiltonian dynamics simulation, magnetization, can be efficiently simulated on current superconducting qubit based programmable quantum annealing computers. This can be done using two distinct methods; reverse quantum annealing and h-gain state encoding with forward quantum annealing. Each of the two methods use anneal schedules with pauses at varying anneal fractions, small programmed energy scales, and fast quenches to read out the qubit states. This simulation is possible due to the 127 qubit heavy-hex connectivity graph natively embedding onto the D-Wave Pegasus quantum annealers hardware graph, and because there exists a direct equivalence between the energy scales of the two types of quantum computers. We derive equivalent anneal pauses in order to simulate the Trotterized quantum circuit dynamics for varying Rx rotations $\theta_h \in (0, \frac{\pi}{2}]$, using quantum annealing processors. Multiple disjoint instances of the Ising model of interest can be embedded onto the D-Wave Pegasus hardware graph, allowing for parallel quantum annealing. We report equivalent magnetization dynamics using quantum annealing for Trotter step sizes of $20, 50, 100, 200$, which we find are consistent with 27 qubit heavy-hex Trotterized circuit magnetization dynamics, and we observe reasonable, but noisy, agreement with the existing simulations for single site magnetization at 20 Trotter steps.