D-Wave
The Quantum Computing Company™

Qubits Europe 2019

D-Wave Qubits Europe Users Conference 2019
Excelsior Hotel Gallia

The D-Wave team and Data Reply welcome you to Milan!

Conference schedule:

Monday 25 March	18:00 - 20:00	Welcome Reception
Tuesday 26 March	08:30- 18:00	Qubits Conference
	19:00	Group Dinner at Il Tavolino
Wednesday 27 March	08:30- 18:00	Qubits Conference

Register at https://events.eventzilla.net/e/qubits-europe-2019-2138733859

Excelsior Hotel Gallia
Piazza Duca d'Aosta, 9,
20124 Milano MI, Italy

Reserve a room at
https://bit.ly/2CsjIh4

TIME	SESSION
Welcome: Monday 25 March	
Late afternoon	Guests arrive at Excelsior Hotel Gallia
18:00 - 20:00	Registration and Reception at Hotel

Qubits Europe 2019

TIME	SESSION	
Day 1: Tuesday 26 March		
08:00	Registration, Excelsior Hotel Gallia	
QUANTUM COMPUTING: 2019 AND BEYOND		
08:30	Welcome to Qubits from Conference Hosts	Andy Mason, D-Wave, Vern Brownell, D-Wave; Marco Magagnini, Data Reply
09:00	Keynote: Finding Business Value through Quantum Annealing	Marco Magagnini, Data Reply
09:30	North American Qubits Review, Customer Site Reports	René Copeland, D-Wave; Aaron Lott, D-Wave
09:55	USRA Site Report	Davide Venturelli, USRA
D-WAVE DIRECTIONS		
10:15	Company Update	Vern Brownell, D-Wave
10:45	Break	
11:00	Next Generation System	Mark Johnson, D-Wave
11:45	Leap Quantum Application Environment	Murray Thom, D-Wave
12:25	Lunch	
13:25	Los Alamos National Laboratory Site Report	Sue Mniszewski, Los Alamos National Laboratory
APPLICATIONS 1: OPTIMIZATION		
13:45	Flight Gate Assignment with a Quantum Annealer	Tobias Stollenwerk, Elisabeth Lobe, DLR
14:15	Route Optimization for Multimodal Transport Systems	Akira Miki, DENSO
14:45	Quantum Annealing for Asset Sustainment	Aussie Schnore, Annarita Giani GE Research
15:15	Quantum Computing Algorithms for Optimised Planning and Scheduling	Roberto Desimone, Plantagenet
15:45	Break	
16:00	Applications of Quantum Annealing for Blockchain and Allocation of Television Commercials	Tomomitsu Motohashi, Kotaro Tanahashi, Recruit Communications
16:30	Quantum Annealing Based Optimizations of Robotic Movement in Manufacturing	Arpit Mehta, BMW
17:00	Site Report: Quantum Applications and Research Lab (QAR-Lab)	Sebastian Feld, Thomas Gabor, Christoph Roch, LMU
17:30	Pitfalls in Quantum Performance Evaluation	Catherine McGeoch, D-Wave
18:00	Day 1 Wrapup	Andy Mason, D-Wave
19:00	**Dinner: Il Tavolino, Via Gustavo Fara, 23, 20124**	

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TIME	SESSION	
Day 2: Wednesday 27 March		
08:30	Keynote: Hybrid Algorithm Development for Production Applications	Sheir Yarkoni, Volkswagen
APPLICATIONS 2: SCIENCE AND HEALTHCARE		
09:10	Complete Protonation Behaviour of Intrinsically Disordered Proteins through Quantum Annealing	Matt Heberling, Peptone
09:50	Quantum Chemistry on Quantum Annealers	Scott Genin, OTI
10:20	Break	
10:35	Statistical Classification of High-throughput Multi-omics Cancer Data on Quantum Computing Architecture	Tom Chittendon, WuXi NextCODE Genomics
ANNEALING FEATURES, NEW ALGORITHMS, METHODS		
11:05	Quantum Annealing with Continuous Variables: an Application to Matrix Factorization	Daniele Ottaviani, Cineca
11:35	A Hybrid Quantum-Classical Recommendation System	Andrea Skolik, Volkswagen
12:05	Susceptibility Measurements on the DW-2000Q	Edward Dahl, D-Wave
12:35	Lunch	
13:35	OpenJij: An Open-source Project Towards a Unified Annealing Platform	Yu Yamashiro, Jij
14:05	Challenging Collaborations with T-QARD	Masayuki Ohzeki, Tohoku University
14:50	Partition of Large Optimization Problems with One-hot Constraint	Shuntaro Okada, DENSO
15:20	Break	
QUANTUM AS A BUSINESS		
15:35	Quantum Business in Japanese market	Yuichiro Minato, MDR Inc
16:05	Our Experience Developing An Optimization Service Using D-Wave	Eihiro Saishu, Groovenauts, Inc
APPLICATIONS 3: OPTIMIZATION		
16:35	Quantitative Reverse Stress Testing using Simulated and Quantum Annealig Applied to XVA	Assad Bouayoun, HSBC
17:05	Allocating Railway Traffic with QUBO Formulated Models	Davide Caputo, Data Reply, Lorenzo Ferrone, FSI
17:35	Conference Wrapup	Vern Brownell and Andy Mason, D-Wave
17:45	End of Qubits Europe 2019	

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Selected Abstracts

Title: Flight Gate Assignment with a Quantum Annealer
Speakers: Tobias Stollenwerk, Elisabeth Lobe, German Aerospace Center (DLR)
Optimal flight gate assignment is a highly relevant optimi-zation problem from airport management. Among others, an important goal is the minimization of the total transit time of the passengers. The corresponding objective function is quadratic in the binary decision variables encoding the flight-to-gate assignment. Hence, it is a quadratic assignment problem being hard to solve in general. In this work we invesigate the solvability of this problem with a D-Wave quantum annealer. These machines are optimizers for quadratic unconstrained optimization problems (QUBO). Therefore the flight gate assignment problem seems to be well suited for these machines. We use real world data from a mid-sized German airport as well as simulation based data to extract typical instances small enough to be amenable to the D-Wave machine. In order to mitigate precision problems, we employ bin packing on the passenger numbers to reduce the precision requirements of the extracted instances. We find that, for the instances we investigated, the bin packing has little effect on the solution quality. Hence, we were able to solve small problem instances extracted from real data with the D-Wave 2000Q quantum annealer.

Title: Route Optimization for Multimodal Transport Systems
Speaker: Akira Miki, DENSO
Toward the realization of efficient multimodal transport systems, we develop a method of route optimization and perform the optimization by using D-Wave 2000Q. The multimodal transport system consists of both small vehicles like taxies and large vehicles like buses, which provides efficient transportation for customers who are similar in the directions of departure and destination. The target of our present study is to minimize the total distances of both small and large vehicles. Decision variables in our optimization are not only the variables corresponding to the routes of small and large vehicles but also the variables corresponding to the selection of junctions of small and large vehicles. To use Ising machines, we develop a method to represent the optimization by QUBO formulation. In the presentation, we explain the problem setting and our QUBO formulation and show obtained results by using D-Wave 2000Q.

Title: Quantum Annealing for Asset Sustainment
Speakers: Aussie Schnore, Annarita Giani, GE Research
Sustainment planning and resource allocation are core problems in logistics. Sophisticated algorithms and techniques are used to find the optimal allocation strategies for resources needed for concurrent repairs. But the used methodologies do not scale, so logistician often rely on domain knowledge and heuristics. This allows for less than ideal results. Quantum annealing quickly searches over a space and finds an optimal solution. In this talk we present how we mapped a sustainment optimization problem to a suitable format for quantum acceleration. We will show how to formulate the resource allocation problem as a Quadratic Unconstrained Binary Optimization (QUBO), which is suitable for a D-Wave quantum computer, share our results and make some observations about where improvements in the process introduced will need to be made..

Title: Quantum Computing Algorithms for Optimised Planning and Scheduling
Speaker: Roberto Desimone, Plantagenet
Roberto Desimone will be presenting results of his InnovateUK feasibility study on 'quantum computing algorithms for optimised planning and scheduling' that was completed in Oct 2018. The aim of the project was to explore the technical/business feasibility of enhancing existing techniques for optimising planning and scheduling tasks with quantum algorithms and to explore specific market applications of these hybrid techniques for distribution logistics/traffic-flow optimisation, operations management and telecommunications networks. The project included experiments with the quantum annealing systems from D-Wave Systems on a variety of optimisation problems and a comparative analysis with other universal (circuit-model) quantum computing (QC) approaches. An innovation workshop was held, involving more than 50 people from key industry sectors (potential end-users), as well as quantum computing experts from academia/industry and other quantum stakeholders/fund-holders. The results of the experiments and workshop outputs have informed the market assessment/roadmaps for exploiting quantum algorithms for optimised planning/ scheduling tasks, and will inform the 'road-mapping' activity currently sponsored by InnovateUK and supported by the UK Quantum Technology Programme.

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Title: Applications of Quantum Annealing for Blockchain and Allocation of Television Commercials
Speakers: Tomomitsu Motohashi, Kotaro Tanahashi, Recruit Communications

In the first part of the presentation we will introduce a blockchain consensus algorithm based on quantum annealers. The blockchain is expected to be used in various fields as a decentralized application platform such as cryptocurrency. In the blockchain technology, Proof of Work (PoW) has been adopted as a significant consensus algorithm to avoid tampering of data records. Since PoW needs a massive calculation process, called mining, enormous electricity usage for keeping the platform and much lead time to commit transaction are required. In our study, we propose a new method in which a problem that cannot be solved quickly by conventional digital computers but can be solved in a short time by quantum annealing processor is adopted as a mining problem of PoW.Our scheme is as follows. First, we set the seed of random number from the committed data. Next, we generate a couple of problems in which the parameters in quadratic unconstraint binary optimization (QUBO) are prepared randomly. Also, the target value of cost function is set up. In our method, the mining is regarded to find better solutions for a certain number of problems in the generated problems. In our presentation, we will show the essential concept and the efficiency of our strategy. In the second part of the presentation, we will introduce the optimization of the television commercial (TVC). In the TVC optimization, we maximize the number of viewers who have watched the target TVCs more than k times by choosing appropriate time and channel. Because this problem is non-linear discrete optimization problem, conventional solver cannot efficiently solve the problem. We will show how to efficiently use quantum annealer for the TVC optimization.

Title: Quantum Annealing Based Optimizations of Robotic Movement in Manufacturing
Speaker: Arpit Mehta, BMW

Recently, considerable attention has been paid to planning and scheduling problems for multiple robot systems (MRS). Such attention has resulted in a wide range of techniques being developed in solving more complex tasks at ever increasing speeds. At the same time, however, the complexity of such tasks has increased as such systems have to cope with ever increasing business requirements, rendering the above mentioned techniques unreliable, if not obsolete. Quantum computing is an alternative form of computation that holds a lot of potential for providing some advantages over classical computing for solving certain kinds of difficult optimization problems in the coming years. Motivated by this fact, in this talk we demonstrate the feasibility of running a particular type of optimization problem on existing D-Wave Quantum Annealer. The optimization problem investigate arises when considering how to optimize a robotic assembly line, which is one of the keys to success in the manufacturing domain. A small improvement in the efficiency of such an MRS can lead to huge saving in terms of time of manufacturing, capacity, robot life, and material usage. The nature of the quantum processor used in this study imposes the constraint that the optimization problem be cast as a quadratic unconstrained binary optimization (QUBO) problem. For the specific problem we investigate, this allows situations with one robot to be modeled naturally, meanwhile modeling the multi-robot generalization is less obvious and left as a topic for future research. The results show that for simple 1-robot tasks, the optimization problem can be straightforwardly solved within a feasible time span on existing quantum computing hardware.

Title: Site Report: Quantum Applications and Research Lab (QAR-Lab)
Speakers: Sebastian Feld, Thomas Gabor, Christoph Roch, LMU

This talk will be divided into two parts: (1) activities of the QAR-Lab related to quantum annealing, and (2) presentation of novel research results with regard to quantum annealing.

ACTIVITIES: The topic quantum computing and in particular quantum annealing has been incorporated into the lectures "Computer Architecture" and "Internet of Things" of the LMU Munich. The QAR-Lab organizes the "First International Workshop on Quantum Technology and Optimization Problems" (QTOP 2019) that will be held on March 18 in Munich. There are 18 accepted full papers from the topics analysis of optimization problems, quantum gate algorithms, applications of quantum annealing, and foundations of quantum technologies.

RESULTS: At last year's Qubits Europe we have presented preliminary results on the capacitated vehicle routing problem. This year we would like to update that information and give the final results that are now published respectively under review. Furthermore we would like to present our published research results regarding the optimization of geometry compression using quantum annealing. In the field of computer vision, the representation of 3D point clouds using constructive solid geometry is state-of-the-art. Additionally, we present the current state of our research regarding the gate assignment problem. These results come from a concrete project with a partner from the aviation industry. Finally, we pitch the latest results of ongoing bachelor's and master's theses, that can serve as a base for a fruitful discussion.

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Title: Pitfalls in Quantum Performance Evaluation
Speaker: Catherine McGeoch, D-Wave
Sometimes it can be difficult to interpret the results of an experiment comparing performance of your favorite quantum annealer versus classical alternatives. This talk gives some advice for avoiding pitfalls that lead to inconclusive results or incorrect conclusions.

Title: Keynote: Hybrid Algorithm Development for Production Applications
Speaker: Sheir Yarkoni, Volkswagen
In recent years many advancements have been made in the field of prototype application development for current-generation quantum computers. Problems such as traffic flow optimization, machine learning, scheduling, and others have all shown the ability to benefit from quantum acceleration. In this talk we demonstrate how we are working to extend those prototypes to be suitable for production applications that involve live data. Specifically we look at building a hybrid algorithm that will be used as part of a smart mobility solution at the Web Summit 2019 provided by Volkswagen. We investigate both the construction of the quantum-classical algorithm as well as the infrastructure requirements involved in using a quantum processor in a live production setting.

Title: Complete Protonation Behaviour of Intrinsically Disordered Proteins through Quantum Annealing
Speaker: Matt Heberling, Peptone
Intrinsically disordered proteins (IDPs) are a sizable yet elusive class of polypeptides implicated in numerous debilitating human disorders, including Alzheimer's and Parkinson's . Local electrostatics and protonation define their structural, dynamicand intra-molecular properties in cellular context. Recent evidence suggests that comprehensive and accurate protonation behavior of disordered polypeptides can be obtained in statistical mechanics simulations, which conceptually resemble the Ising Hamiltonian, a known NP-hard problem. Quantum computing holds promise of addressing the limitations of classical calculations for biophysical processes, however very few examples of practical importance for experimental protein biophysics have been reported. We describe here a novel approach for simulating complete protonation behaviour in intrinsically disordered polypeptides using a quantum annealing processor and compare it against residual protonation profiles for human alpha-synuclein (aS) obtained in solution-state NMR spectroscopy experiments.

Title: Quantum Chemistry on Quantum Annealers
Speaker: Scott Genin, OTI
Quantum chemistry calculations for small molecules on quantum hardware have been demonstrated to date only on universal-gate quantum computers, not quantum annealers. The latter devices are limited to finding the lowest eigenstate of the Ising Hamiltonian whereas the electronic Hamiltonian could not be mapped to the Ising form without exponential growth of the Ising Hamiltonian with the size of the system [J. Phys. Chem. B 122, 3384 (2018)]. Here we propose a novel mixed discrete-continuous optimization algorithm, which finds the lowest eigenstate of the qubit coupled cluster (QCC) method using a quantum annealer for solving a discrete part of the problem. The QCC method is a potentially exact approach for constructing the electronic wave function in the qubit space. Therefore, our methodology allows for systematically improvable quantum chemistry calculations using quantum annealers. We illustrate capabilities of our approach by calculating QCC ground electronic states for the LiH, H2O, and C6H6 molecules. C6H6 calculations involve 36 qubits and are the largest quantum chemistry calculations made on a quantum annealer (the D-Wave 2000Q system) to date. Our findings opens up a new perspective for use quantum annealers in high-throughput material discovery.

Title: Statistical Classification of High-throughput Multi-omics Cancer Data on Quantum Computing Architecture
Speaker: Tom Chittendon, WuXi NextCODE Genomics
Next-generation sequencing has significantly advanced our understanding of biology by providing a unique genomic perspective of the molecular state of human disease. However, combining multiple 'omics' measurements into biologically-relevant statistical computing frameworks to define causal molecular underpinnings of disease remains a significant challenge. As a rapidly emerging technology, quantum computing promises to enhance performance of certain classes of statistical computing and machine learning tasks, such as classification, regression, and generation. Anticipating its utility in the biomedical sciences, we implemented several quantum statistical machine learning (qML) strategies on a simulated universal quantum computer and a physical quantum annealer. We show the utility of multiple classes of qML algorithms for analysis of high-dimensional, multi-omic patient data from the Cancer Genome Atlas (TCGA). To assess algorithm performance, we compared these quantum classifiers to a variety of classical statistical machine learning methods. Our results indicate statistically significant binomial and multinomial quantum classification of TCGA cancer types and associated molecular subtypes, thus providing compelling empirical evidence for the potential of this emerging field.

Selected Abstracts

Title: Quantum Annealing with Continuous Variables: an Application to Matrix Factorization
Speaker: Daniele Ottaviani, Cineca
In this work it is shown how the quantum annealing process is able to find global optima even in the case of problems that do not directly involve binary variables. The problem addressed is the following: taking a matrix V, find two matrices W and H such that the norm between V and the matrix product W·H is as small as possible. The factorization foresees that the matrix W is composed of real numbers between 0 and 1 and that the sum of its rows is equal to 1. The QUBO problem associated with this type of factorization generates a potential composed of many local minima. We show that simple forward-annealing techniques are not sufficient to solve the problem. The new D-Wave 2000Q has introduced new solution refinement techniques, including reverse-annealing. Reverse-annealing allows to explore the configuration space starting from a point chosen by the user, for example a local minimum obtained with a precedent forward-annealing. In this article we propose an algorithm based on the reverse annealing technique (that we called adaptive reverse annealing) able to reach global minimum even in the case of QUBO problems where the classic forward annealing, or uncontrolled reverse annealing, cannot reach satisfactory solutions.

Title: A Hybrid Quantum-Classical Recommendation System
Speaker: Andrea Skolik, Volkswagen
Inspired by work on nonnegative/binary matrix factorization (NBMF) presented at last year's Qubits, we built a hybrid quantum-classical recommender system. The recommender system is based on NBMF, and partially run on D-Wave quantum processors to generate recommendations based on previous user interaction data. We present the results generated by our algorithm, and ideas on how this kind of recommender system could be used within Volkswagen.

Title: Susceptibility Measurements on the DW-2000Q
Speaker: Edward Dahl, D-Wave
Susceptibility is a simple concept – it is the linear response of a physical system property to some stimulus. With magnetic materials, we can apply an external magnetic field and measure the system's magnetization. The ratio of the response to the applied magnetic field is susceptibility. The new h-gain feature on the D-Wave 2000Q allows us to introduce a magnetic field partway through the annealing cycle. We use this mechanism to see a phase transition in a two dimensional toroidal transverse field Ising antiferromagnet.

Title: OpenJij: An Open-source Project Towards a Unified Annealing Platform
Speaker: Yu Yamashiro, Jij
Jij Inc. is a venture company developing software for annealing-based optimization established with the support of JST (Japan Science and Technology Agency)-START project. We are starting an open-source project named "OpenJij" towards a unified platform for various annealing machines. OpenJij provides the environment for developing annealing applications, evaluating the performance, and benchmarking. In this talk, we will introduce the overview and features of OpenJij and our company's efforts.

Title: Challenging collaborations with T-QARD
Speaker: Masayuki Ohzeki, Tohoku University
We show our recent activity on application of the quantum annealer, namely the D-Wave 2000Q, in collaboration with several companies in Japan.
1. DENSO CORP. - In the present study, we utilize the D-Wave 2000Q in the black-box optimization via a formulation of the QUBO to solve a wide range of combinatorial optimization problems and show its comparison with several techniques such as semi-definite programing, simulated annealing and digital annealer.
2. Nomura Asset Management Co., Ltd. - We test the sampling technique of the D-Wave 2000Q to implement the Boltzmann machine learning for inferring correlation between future stock returns and their features.
3. Kyocera Corp. - A graph partitioning of water cluster was performed by the D-Wave 2000Q, and the performance is assessed by taking a comparison with conventional graph partitioning algorithm. We demonstrate that the partitioning approach by D-Wave 2000Q is the best approach for dividing the water cluster.
4. Hachinohe High School - We formulate a bus scheduling problem as the Ising model to solve it via D-Wave 2000Q. Our formulation of the bus scheduling problem identifies a way to optimize the number of the buses and reduce the excess waiting time by solving the Ising model.

In addition, we demonstrate our new algorithm to enhance the capability to solve large size problems via the D-Wave 2000Q without division into subproblems.

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Title: Partition of Large Optimization Problems with One-hot Constraint
Speaker: Shuntaro Okada, DENSO
It is, in general, hard to embed all of the logical variables of large-scale optimization problems due to limitations of the number of qubits and connectivity in the current version of the D-Wave system. To handle such a large problem, the original large problems are usually partitioned into embeddable subproblems, and they are optimized iteratively. In this scheme, it is essential that subproblems include as many spin configurations which satisfy constraints of the original large problem as possible, to obtain high-accuracy solutions. In this talk, we propose two generic methods to extract subproblems from large optimization problems with one-hot constraint.The performance of our proposed method is assessed for several large Potts models using the D-Wave system combined with the embedding algorithm proposed in Ref. [1], and we discuss differences between the two proposed methods.

Title: Quantum Business in Japanese market
Speaker: Yuichiro Minato, MDR Inc
Japanese domestic companies are very familiar with quantum machines. We introduce some case studies on finance and automotive, how to do business, and why our clients accept quantum machines for their future business plans.

Title: Our Experience Developing An Optimization Service Using D-Wave
Speaker: Eihiro Saishu, Groovenauts
At Groovenauts, we offer a cloud-based machine learning service, MAGELLAN BLOCKS, that requires no programming ability. As more users train accurate predictive models, many are now looking for ways to use their machine learning results for combinatorial optimizations. To meet this need, we are developing a non-programming optimization service to go along with MAGELLAN BLOCKS. We would like to share the outline and background of this service, along with our experience developing it to help meet our customers' needs.

Title: Quantitative Reverse Stress Testing using Simulated and Quantum Annealig Applied to XVA
Speaker: Assad Bouayoun, HSBC
Financial stress testing is becoming a dominant part of the arsenal built by regulators to protect the economic stability against the fall of one or a series of financial institutions. To avoid a combinatorial explosion, a number of arbitrary choices are usually made in relation to the level of each shock, their combination and the time horizon. These assumptions although necessary, are limiting the effectiveness of this technique. This talk investigates the possibility of reverse stress testing by inferring the combination of shocks maximising the XVA loss at a particular time horizon using simulated and quantum annealing. A reformulation of the reverse stress testing as a quadratic unconstrained binary optimisation and its resolution using first and second derivatives is proposed.

Title: Allocating Railway Traffic with QUBO Formulated Models
Speakers: Davide Caputo, Data Reply, Lorenzo Ferrone, FSI
The Trains Platforming Problem (TPP) is the task of allocating a platform to trains arriving in a railway station. This problem is intrinsically quadratic and computationally challenging due to both the high dimensionality of the solution space and the deep variables connectivity. In this work, the Innovation Team of Ferrovie Dello Stato and Data Reply report about the QUBO formulation for the TPP they've developed together and the potential implications of this type of models on the infrastructures of the railway network.