Nathan Wiebe

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Education

BSC | MAY 2002 | SIMON FRASER UNIVERSITY

- Major: Mathematical Physics

MSC | SEPT 2005 | SIMON FRASER UNIVERSITY

- Major: Physics

PHD | JUNE 2011| UNIVERSITY OF CALGARY

- Major: Physics

Skills & Abilities

SKILLS

I am a specialist in quantum algorithms who primarily focuses on algorithms for quantum machine learning, quantum simulation and statistical inference as well as machine learning.

RESEARCH

- J Biamonte, P Wittek, N Pancotti, P Rebentrost, N Wiebe, S Lloyd. "Quantum machine learning" Nature 549 (7671), 195 (2018).
- Gilyén, A., Su, Y., Low, G. H., & Wiebe, N. (2018). Quantum singular value transformation and beyond: exponential improvements for quantum matrix arithmetics. arXiv preprint arXiv:1806.01838.
- Gilyén, A., Arunachalam, S., & Wiebe, N. (2017). Optimizing quantum optimization algorithms via faster quantum gradient computation. arXiv preprint arXiv:1711.00465. (To appear in SODA 2019)
- Lumino, A., Polino, E., Rab, A. S., Milani, G., Spagnolo, N., Wiebe, N., & Sciarrino, F. (2018). Experimental Phase Estimation Enhanced by Machine Learning. Physical Review Applied, 10(4), 044033.
- Wiebe, N., & Kumar, R. S. S. (2018). Hardening quantum machine learning against adversaries. New Journal of Physics.
- Schuld, M., Bocharov, A., Svore, K., & Wiebe, N. (2018). Circuit-centric quantum classifiers. arXiv preprint arXiv:1804.00633.
- Low, G. H., & Wiebe, N. (2018). Hamiltonian Simulation in the Interaction Picture. arXiv preprint arXiv:1805.00675.
- Giordani, T., Flamini, F., Pompili, M., Viggianiello, N., Spagnolo, N., Crespi, A., ... & Sciarrino, F. (2018, September). Signature of multi-photon interference in boson sampling experiments. In Quantum Photonic Devices 2018 (Vol. 10733, p. 107330T). International Society for Optics and Photonics.
- Ian D Kivlichan, Jarrod McClean, Nathan Wiebe, Craig Gidney, Alán Aspuru-Guzik, Garnet Kin-Lic Chan, Ryan Babbush "Quantum simulation of electronic structure with linear depth and connectivity" Physical review letters 120 (11), 110501 (2018)
- Ryan Babbush, Nathan Wiebe, Jarrod McClean, James McClain, Hartmut Neven, Garnet Kin-Lic Chan. "Low-depth quantum simulation of materials" Physical Review X 8 (1), 011044 (2018)
- "Experimental statistical signature of many-body quantum interference" Nature Photonics 12 (3), 173 (2018)
- Raffaele Santagati, J Wang, AA Gentile, S Paesani, N Wiebe, J McClean, SR Morley-Short, PJ Shadbolt, D Bonneau, JW Silverstone, DP Tew, X Zhou, JL O'Brien, MG Thompson. "Witnessing eigenstates for quantum simulation of Hamiltonian spectra" Science Advances 26: Vol. 4, no. 1, eaap9646 (2018)

- Dominic W Berry, Mária Kieferová, Artur Scherer, Yuval R Sanders, Guang Hao Low, Nathan Wiebe, Craig Gidney, Ryan Babbush. "Improved techniques for preparing eigenstates of fermionic Hamiltonians" npj Quantum Information 4 (1), 22 (2018)
- Santagati, R., Gentile, A. A., Knauer, S., Schmitt, S., Paesani, S., Granade, C., ... & Thompson, M. G. (2018). Magnetic-field-learning using a single electronic spin in diamond with one-photon-readout at room temperature. arXiv preprint arXiv:1807.09753.
- Soeken, M., Roetteler, M., Wiebe, N., & De Micheli, G. (2018). LUT-based Hierarchical Reversible Logic Synthesis. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems.
- G Meuli, M Soeken, M Roetteler, N Wiebe, G De Micheli. "A best-fit mapping algorithm to facilitate ESOP-decomposition in Clifford+ T quantum network synthesis" Proceedings of the 23rd Asia and South Pacific Design Automation Conference 664-669 (2018)
- Jianwei Wang, Stefano Paesani, Raffaele Santagati, Sebastian Knauer, Antonio A Gentile, Nathan Wiebe, Maurangelo Petruzzella, Jeremy L O'Brien, John G Rarity, Anthony Laing, Mark G Thompson. "Experimental quantum Hamiltonian learning" Nature Physics 13 (6), 551 (2017)
- Stefano Paesani, Andreas A Gentile, Raffaele Santagati, Jianwei Wang, Nathan Wiebe, David P Tew, Jeremy L O'Brien, Mark G Thompson. "Experimental Bayesian quantum phase estimation on a silicon photonic chip" Physical review letters 118 (10), 100503 (2017)
- C Granade, N Wiebe. "Structured filtering" New Journal of Physics 19 (8), 083014 (2017).
- M Reiher, N Wiebe, KM Svore, D Wecker, M Troyer. "Elucidating Reaction Mechanisms on Quantum Computers" Proceedings of the National Academy of Sciences, 201619152 (2017).
- M Kieferová, N Wiebe. "Tomography and generative training with quantum Boltzmann machines" Physical Review A 96 (6), 062327 (2017)
- ID Kivlichan, N Wiebe, R Babbush, A Aspuru-Guzik. "Bounding the costs of quantum simulation of many-body physics in real space" Journal of Physics A: Mathematical and Theoretical 50 (30), 305301 (2017).
- N Wiebe, C Granade. "Can small quantum systems learn?" QIC, Vol 17 No 7-8 pp0568-0594 (2017).
- M Soeken, M Roetteler, N Wiebe, G De Micheli. "Hierarchical reversible logic synthesis using LUTs" Design Automation Conference (DAC), 2017 54th ACM/EDAC/IEEE, 1-6 (2017)
- M Roetteler, KM Svore, D Wecker, N Wiebe. "Design automation for quantum architectures" 2017 Design, Automation & Test in Europe Conference & Exhibition (DATE) 1312-1317 (2017).
- M Soeken, M Roetteler, N Wiebe, G De Micheli. "Design automation and design space exploration for quantum computers" Proceedings of the Conference on Design, Automation & Test in Europe, 470-475 (2017).
- N Wiebe, A Kapoor, KM Svore. "Quantum Perceptron Models" Advances in Neural Information Processing Systems, 3999-4007 (2016).
- I Zintchenko, N Wiebe. "Randomized gap and amplitude estimation", Physical Review A 93 (6), 062306 (2016).
- N Wiebe, C Granade. "Efficient Bayesian Phase Estimation", *Physical Review Letters*, 117(1), 1-6 (2016)
- D Wecker, MB Hastings, N Wiebe, BK Clark, C Nayak, M Troyer. "Solving strongly correlated electron models on a quantum computer". Physical Review A 92 (6), 062318 (2015).
- N Wiebe, A Kapoor, KM Svore. "Quantum Nearest-Neighbor Algorithms for Machine Learning". Quantum Information and Computation 15, 318-358 (2015).
- R Babbush, J McClean, D Wecker, A Aspuru-Guzik, N Wiebe. "Chemical basis of Trotter-Suzuki errors in quantum chemistry simulation". Physical Review A 91, 022311 (2015).
- D Poulin, MB Hastings, D Wecker, N Wiebe, AC Doherty, M Troyer. "The Trotter Step Size Required for Accurate Quantum Simulation of Quantum Chemistry". Quantum Information and Computation 15, 0361-0384 (2015).
- N Wiebe, C Granade, DG Cory. "Quantum bootstrapping via compressed quantum Hamiltonian learning". New Journal of Physics 17, 022005 (2015).
- N Wiebe, A Kapoor, KM Svore. "Quantum Deep Learning", Quantum Information and Computation 16, 0541-0587 (2016).
- N Wiebe, M Roettler. "Quantum arithmetic and numerical analysis using Repeat-Until-Success circuits", Quantum Information and Communication 16, 134-178 (2016).
- N Wiebe. "Using Quantum Computing to Learn Physics" Bulletin of EATCS 1 (112) (2014).
- N Wiebe, C Granade, DG Cory. "Quantum Hamiltonian Learning Using Imperfect Quantum Resources". Physical Review A 89, 042314 (2014).

- M. Kieferova, N Wiebe. “On The Power Of Coherently Controlled Quantum Adiabatic Evolutions”. New Journal of Physics 16, 123034 (2014).
- N Wiebe, V Kliuchnikov. “Floating Point Representations in Quantum Circuit Synthesis”. New Journal of Physics 15, 093041 (2013)
- MP Mueller, E Adlam, L Masanes, N Wiebe, “Thermalization and canonical typicality in translation-invariant quantum lattice systems”. Communications in Mathematical Physics 340, 499-561 (2015).
- N Wiebe, C Granade, C Ferrie, DG Cory. “Hamiltonian learning and certification using quantum resources”, Physical Review Letters 112, 190501 (2013).
- V Veitch, N Wiebe, C Ferrie, J Emerson. “Efficient simulation scheme for a class of quantum optics experiments with non-negative Wigner representation”. New Journal of Physics 15, 013037 (2013)
- C. Ududec, N. Wiebe, J. Emerson. “Equilibration of Measurement Statistics Under Complex Dynamics”. To appear in Physical Review Letters 111, 080403 (2013).
- A. M. Childs, N. Wiebe. “Product Formulas for Exponentials of Commutators”, J. Math. Phys. **54**, 062202 (2013).
- V. Veitch, N. Wiebe, C. Ferrie, J. Emerson “Efficient simulation scheme for a class of quantum optics experiments with non-negative Wigner representation”. New Journal of Physics 15, 013037 (2013).
- S. Raeisi, N. Wiebe, B. C. Sanders “Designing Quantum Circuits for Efficient Many-Body Quantum Simulation”. New Journal of Physics 14, 103017 (2012).
- C. Granade, C. Ferrie, N. Wiebe, D. Cory “Robust Online Hamiltonian Learning”. New Journal of Physics 14, 103013 (2012).
- N. Wiebe, D. Braun, S. Lloyd “Quantum Algorithm for Data Fitting”, Phys. Rev. Lett. 109, 50505 (2012).
- A. M. Childs, N. Wiebe “Hamiltonian Simulation Using Linear Combinations of Unitary Operations”. Quantum Information and Computation 12, 901-924 (2012). (alphabetical author ordering)
- N. Wiebe, N. Babcock “Improved error-scaling for adiabatic quantum evolutions”. New Journal of Physics 14, 013024 (2012).
- D. Cheung, P. Hoyer, N. Wiebe “Improved error bounds for the adiabatic approximation”. J. Phys. A 44, 415302 (2011). (alphabetical author ordering)
- N. Wiebe, D. W. Berry, P. Hoyer and B. C. Sanders “Simulating quantum dynamics on a quantum computer” J. Phys. A 44, 445308 (2011).
- N. Wiebe, D. W. Berry, P. Hoyer and B. C. Sanders “Higher order decompositions of ordered operator exponentials” J. Phys. A 43, 065203 (2010).
- N. Wiebe and L.E. Ballentine “The Quantum Mechanics of Hyperion”, Phys. Rev. A 72, 022109 (2005).

TEACHING

- “Quantum Machine Learning Using Q-Sharp”, 1 day lecture as part of Microsoft’s MLADS 2018 conference.
- “Quantum Machine Learning”, 1 day lecture as part of Microsoft’s MLADS 2017 conference.
- “Introduction to quantum computing”, day long tutorial taught to developers at Microsoft Garage 2017.
- “Introduction to Quantum Computing”, Month long course taught at MSR in 2015.
- “Quantum Simulation”, Month Long Graduate course taught at University of Waterloo in 2012.
- Co-Instructed “Introduction to Electromagnetism” at the university of Calgary 2008-2011. Responsibilities included designing lectures, grading lectures and coordinating content with the other instructors.

SUPERVISING

- Sadegh Raeisi 2009-2010, Co-Supervised Masters Student.
  Work showed an improved method for simulating quantum many-body dynamics on quantum computers.
  Student went on to become an assistant professor at Sharif In Iran.
- Ryan Babbush 2014, Summer Intern.
  Work revealed that the cost of quantum chemistry simulation depends on physical parameters of the system.
  Went on to lead Google’s quantum chemistry simulation effort in Venice Beach.

- Ilia Zintchenko 2015, Summer Intern.
  Work provided fast methods for optimizing simulated annealing code and also new quantum algorithms for phase estimation.
  Went on to found his own startup Ntropy.
- Maria Kieferova 2009-2016, Co-Supervised MSc Thesis and Summer intern 2016.
  Work led to a fundamentally new way to do adiabatic optimization and the first fully quantum algorithms for Boltzmann machine training.
  Currently finishing her PhD at Macquarie University in Sydney.
- Andras Gilyen 2017, Summer intern.
- Work gave a query optimal quantum algorithm for computing gradients and unified quantum simulation, quantum walks and many quantum machine learning algorithm. Presented at QIP.
  Student is currently a PhD student at CWI in the Netherlands.
- Jana Darulova, Co-Supervised Intern 2017.
  Her work provided practical ways to use machine learning to characterize quantum dot devices.
  She is currently a PhD student at the University of Sydney.
- Maria Shuld, Co-Supervised Intern 2017.
  Her work identified a new class of quantum neural networks that perform as well as classical networks but with fewer weights than commonly used networks.
  She currently is a staff scientist at Xanadu.
- Ian Kivlichan, Intern 2017.
  His work focused on improving quantum simulation using improved phase estimation techniques.
  He is currently a PhD student at Harvard.
- Anirban Chowdhury, Supervised Intern 2018
  His work focused on finding improved ways to prepare thermal distributions on quantum computers.
  He is currently a PhD student at the university of New Mexico and Los Alamos National Labs
- Yuan Su, Intern 2018.
  His work focused on rigorously bounding the query complexity for the most popular forms of quantum simulation.
  He is currently finishing his PhD at the university of Maryland.
- Natalie Klco, Intern 2018.
  Natalie's work focused on optimizing and understanding the errors in quantum simulation algorithms and has led to a new family of simulation algorithms that use sort networks as their primitives.
  She is finishing her PhD at the university of Washington.
- Leonard Wossnig, Intern 2018.
  His work focused on building new classes of quantum recurrent neural networks that can be used to identify salient features of quantum states and generate new states based on training data.
  He is currently a PhD student at University College London.

PATENTS

- N Wiebe, A Kapoor, K Svore "Method and system for computing distance measures on a quantum computer" (2013).
- N Wiebe, M Roetteler "Quantum algorithms for arithmetic and function synthesis" (2014)
- N Wiebe, A Kapoor, K Svore "Quantum deep learning" (2014)
- N Wiebe, A Kapoor, K Svore, C Granade "Fast low-memory methods for Bayesian inference, Gibbs sampling and deep learning" (2015)
- N Wiebe, C Granade "Efficient online methods for quantum Bayesian inference" (2015)
- I. Zintchenko, N Wiebe "Randomized gap and amplitude estimation" (2015)
- I. Zintchenko, M Hastings, N Wiebe, M Troyer "Partial Reinitialization for optimizers" (2015)
- M Kieferova, N Wiebe "TOMOGRAPHY AND GENERATIVE DATA MODELING VIA QUANTUM BOLTZMANN TRAINING" (2016).
- C Granade, N Wiebe "Random Walk Phase Estimation" (2017)

- N Wiebe, R K Shankar “Adversarial Quantum Machine Learning” (2017).
- G H Low, N Wiebe. Hamiltonian simulation in the interaction picture (2018), ,
- A Gilyen, N Wiebe “Phase arithmetic for quantum computation” (2018),

COMMUNICATION

- Keynote Speaker: Quantum Simulation and Computation, Bilbao Spain 2018.
- Invited Speaker: Q2B Conference in Mountainview 2018.
- Invited Speaker: Quantum Machine Learning & Biomimetic Quantum 2018.
- Invited Speaker: Challenges in Quantum Computing (Simons Institute) 2018.
- Invited Speaker: Quantum computing: from advantage to applications – IBM 2017.
- Invited Speaker: Scalable Architectures for Quantum Simulation, 2017.
- Invited Speaker: SQUINT 2017, Baton Rouge. USA 2017.
- Invited Speaker: International Conference on Integrated Quantum Photonics 2017.
- Invited speaker: Microsoft Station Q meeting, Santa Barbara. USA 2016.
- Invited speaker: Google, Venice, USA 2016.
- Invited speaker: Quantum Alberta Workshop, Banff, Canada 2016.
- Invited speaker: Quantum Computer Science, Banff, Canada 2016.
- Invited speaker: Aspen Winter Conference on Advances in Quantum Algorithms and Computation. Aspen, USA 2016.
- Invited speaker: NASA Ames. Mountain View, USA 2016.
- Invited speaker: Microsoft Faculty Summit, Redmond, USA 2016.
- Invited speaker: Microsoft TechFest, Redmond, USA 2016.
- Invited speaker: Microsoft Latin America Faculty Summit, Rio de Janeiro, Brazil 2016.
- Keynote speaker: Workshop on Photonic Quantum Computing. Bristol, UK 2015.
- Keynote speaker: Microsoft Faculty Summit. Redmond, USA 2015.
- Invited speaker: Workshop on Adiabatic Quantum Computing. Zurich, Switzerland 2015.
- Invited speaker: APS March Meeting. San Antonio, USA 2015.
- Invited speaker: 17th annual Southwest Quantum Information and Technology workshop. Berkeley, USA 2015.
- Invited speaker: NASA Ames. Mountain View, USA 2015.
- Invited speaker: Workshop on Novel Computing Approaches to Quantum Chemistry. Telluride, USA 2015.
- Invited speaker: Quantum Programming and Circuits Workshop. Waterloo, Canada 2015.
- Invited speaker: Center for Quantum Information and Quantum Computing (CQIQC) conference. Toronto, Canada 2015.
- Invited speaker: International Conference on Quantum Simulation. Mountain View, USA 2014.
- Invited speaker: Institute for Quantum Computing colloquium. Waterloo, Canada 2014.
- Best Student Talk, Canadian Quantum Information Students' Conference 2010.
- University of Calgary: Alumni Award Graduate Teaching Award 2007.

LEADERSHIP

- Organized workshop on quantum machine learning as part of NIPS in 2015.
- Organized lecture series on Quantum Annealing at the American Physical Society (APS) March meeting in 2015.
- Drafted the section on quantum machine learning in a Department of Energy (DOE) report on quantum computing in 2015.

- Organized quantum machine learning workshop at Perimeter Institute, Waterloo, in August 2016.
- Member of AQIS 2016 program committee.
- Contributed to organization of successful bid for Quantum Information Processing conference in 2017.
- Associate Editor at the New Journal of Physics since 2017.
- Co-Organized Pracqsys 2017.
- Led writing of technical documents for Q# documentation.
- Served as outreach coordinator for the QuArC and lead Microsoft's quantum device characterization in 2018.

Experience

BSC STUDENT | DOUGLAS COLLEGE, BC, CANADA | 1997-1998

- I studied at Douglas College studying computer science and information technology.

BSC STUDENT | SIMON FRASER UNIVERSITY, BC, CANADA | 1998-2002

- I studied at Simon Fraser University and earned a BSc Honors in Mathematical Physics.

MSC STUDENT | SIMON FRASER UNIVERSITY, BC, CANADA | 2002-2005

- I studied under Leslie Ballentine and served as a teaching assistant

PHD STUDENT | UNIVERSITY OF CALGARY, AB, CANADA | 2005-2011

- I studied under Barry Sanders and Peter Hoyer and served as a teaching assistant as well as project manager for the QViz (Quantum Visualization Project).

POST DOCTORAL FELLOW | UNIVERSITY OF WATERLOO, ON CANADA | APR 2011-JUNE 2013

- My duties involved performing research with members of the institute for quantum computation (IQC) under the supervision of Joseph Emerson and Andrew Childs. During my stay, I pioneered the application of techniques from machine learning and computer vision to the problem of characterizing complex quantum systems. These techniques have exponentially reduced the data required for quantum device characterization. My work also led to the development of several revolutionary new algorithms such as quantum least squares fitting, non-unitary quantum simulation algorithms and improved adiabatic quantum state preparation methods.

POST DOCTORAL RESEARCHER | MICROSOFT RESEARCH, WA, USA | JULY 2013-JULY 2016

- My work at Microsoft focused on answering the question of whether quantum computers can provide a significant advantage for practical machine learning problems. In the course of my work I have shown that quantum computers can significantly speed up nearest neighbor classification, K-means clustering, and certain forms of deep learning. Furthermore, this work also lead to a new quantum inspired efficient classical algorithm for training deep Boltzmann machines that eschews the contrastive divergence approximation completely. My work has also resulted in new quantum algorithms for quantum chemistry that have slashed cost estimates by 8 orders of magnitude and also lead to the first concrete proposals for using small quantum computers to design controls for larger quantum computers.

RESEARCHER | MICROSOFT RESEARCH, WA, USA | JULY 2016- MARCH 2019

- My duties at Microsoft focused on development of quantum algorithms for small, medium and large scale quantum computers. In particular, my work focuses primarily on quantum simulation, quantum machine learning and the use of classical machine learning to solve hard characterization problems for quantum devices.

PHYSICIST | PACIFIC NORTHWEST NATIONAL LABS, WA, USA | JULY 2019 - PRESENT

- My work at PNNL centers around developing quantum algorithms for chemistry, material science and quantum machine learning within the high performance computing group.

AFFILIATE ASSISTANT PROFESSOR | UNIVERSITY OF WASHINGTON, WA, USA | JULY 2019 - PRESENT

- I am also an affiliate professor in the department of physics at the university of Washington. My duties involve advising students, helping design a cohesive quantum strategy for the university and collaborating with the faculty and students of the university on research projects.