

Xiaodi Wu

Assistant Professor

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Research interests

- Quantum Applications in Simulation, Optimization and Machine Learning, Quantum Programming Languages, Formal Methods applied in Quantum Computing, Computer-aided design of Quantum Devices, Quantum Computing Architectures and Systems, Quantum Complexity Theory, Quantum Cryptography, Theory of Computation

Research positions

- 06/2017–
present **Assistant Professor**, *University of Maryland*, College Park, MD.
Department of Computer Science and Institute for Advanced Computer Studies
Fellow of the Joint Center for Quantum Information and Computer Science (QIICS)
- 09/2015–
06/2017 **Assistant Professor**, *University of Oregon*, Eugene, OR.
Department of Computer and Information Science.
- 09/2013–
09/2015 **Postdoctoral Associate**, *Massachusetts Institute of Technology*, Cambridge, MA.
Advisor: Aram Harrow and Scott Aaronson.
- 01/2014–
05/2014 **Simons Research Fellow**, *Simons Institute for the Theory of Computing*, *University of California*, Berkeley, CA, Advisor: Umesh Vazirani.
- Summer
2009,2010 **Research Assistant**, *Institute for Quantum Computing*, *University of Waterloo*, Waterloo, Canada, Advisor: John Watrous.

Education

- 09/2008–
12/2013 **Ph.D. in Computer Science**, *University of Michigan*, Ann Arbor, MI, *GPA: 4.0/4.0*.
Thesis title: *Space-efficient Simulations of Quantum Interactive Proofs*. Advisor: Prof Yaoyun Shi.
- 08/2004–
07/2008 **B.S. in Mathematics and Physics**, *Tsinghua University*, Beijing, China, *GPA: 91/100*.
Thesis title : *Structure Properties of Codeword Stabilized Quantum Error-Correcting Codes*

Honors & Awards

- 11/2020 AFRL/AFOSR Young Investigator Research Program (YIP) Award, 2021.
- 02/2020 NSF CAREER Award, 2020.
- 02/2018 NSF CISE Research Initiation Initiative (CRII) Award, 2018.
- 02/2014 Plenary talk at the 17th Conference on Quantum Information Processing (QIP 2014).
- 02/2013 Simons-Berkeley Research Fellowship (Spring 2014).
- 06/2008 Distinguished Undergraduate Degree Thesis, Tsinghua University.
- 06/2008 Chi-Sun YEH Prize (highest award to undergraduate physics majors), Tsinghua University.
- 06/2007 Microsoft Young Fellow Scholarship, Microsoft Research, Asia.

Funding

Total grants received (my share): \$5.83 million (\$3.04M as PI and \$2.79M as Co-PI)

- NSF CRII: AF: Theoretical Problems in Quantum Computation. Sole PI. \$175,000. NSF-CCF-1755800, 2018-2020.
- DOE ASCR: Quantum Algorithms from the Interplay of Simulation, Optimization, and Machine Learning (17-020469): Co-PI, \$1.35 M (UMD part), my share: \$225,000, 2017-2020.
- NSF AF: Small: Provable Quantum Advantages in Optimization. Sole PI. \$450,000. NSF-CCF-1816695, 2018-2021.
- DOE ASCR: Efficient and Reliable Mapping of Quantum Computations Onto Realistic Architectures in Quantum Testbed Pathfinder Program. Co-PI, with Andrew Childs, Alexey Gorshkov, and Michael Hicks. \$4.47 M in total (my share \$1.12M), 2018-2023.
- AFOSR MURI: Semantics and Structures for Higher-level Quantum Programming Languages. PI at UMD. \$262,380. 2018-2020.
- DOE ASCR: Tough Errors Are no Match (TEAM): Optimizing the quantum compiler for noise resilience. PI at UMD. \$875,000. 2019 - 2024.
- DOE ASCR: Fundamental Algorithmic Research for Quantum Computing (FAR-QC). Co-PI at UMD. my share: \$400,000. 2019 - 2024.
- ARO Quantum algorithms for algebra and discrete optimization. Co-PI, with Andrew Childs, Gorjan Alagic, Yi-Kai Liu, and Carl Miller. \$750,000 in total. (my share:\$150,000.) 2019-2022.
- NSF CAREER:On the Foundations of End-to-End Quantum Applications. Sole PI. \$509,275. NSF-CCF-1942837, 2020-2025.
- NSF Collaborative Research: FET: Medium: Quantum Localization and Synchronization Networks. PI at UMD. \$331,893. NSF-CCF-1955206, 2020-2024.
- DOE QIS Center: The Quantum Science Center. Co-PI at UMD. \$900,000. 2020 - 2025.
- AFOSR Young Investigator Research Program (YIP): Automated Security Analysis of Cryptographic Systems Under Quantum Attacks. Sole PI. \$450,000. 2021-2024.

Patent

- Oct. 2016 **"Physical Randomness Extractors"**, *Kai-Min Chung, Yaoyun Shi, Xiaodi Wu, US Patent 9,471,280.*

Professional service

- PC Member
- ◇ The 9th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2014).
 - ◇ The 20th Annual Conference on Quantum Information Processing (QIP 2017).
 - ◇ The 21th Annual Conference on Quantum Information Processing (QIP 2018).
 - ◇ AAI Conference on Artificial Intelligence (AAAI 2020, 2021).
 - ◇ The 37th International Conference on Machine Learning (ICML 2020).
 - ◇ The 1st International Workshop on Quantum Software Engineering (Q-SE 2020) co-located with the 42nd International Conference on Software Engineering (ICSE 2020).
 - ◇ The 15th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2020).
 - ◇ The 34th Conference on Neural Information Processing Systems (NeurIPS 2020).

- Reviewer
- ◇ *Conferences*: STOC, FOCS, QIP, POPL, SODA, CCC, ICALP, ITCS, CRYPTO, PODC, CCS, AsiaCrypt, TCC, and ISAAC for multiple years.
 - ◇ *Journals*: Journal of the ACM, Nature, Nature Physics, Nature Communications, SIAM Journal of Computing, Quantum Information and Computation, International Journal of Quantum Information, Theoretical Computer Science, Theory of Computing, IEEE Transaction on Information Theory, IEEE Journal on Selected Areas in Information Theory, Physical Review Letter, ACM Transaction on Algorithms, Quantum, and npj Quantum Information.
 - ◇ *Grants*: Natural Sciences and Engineering Research Council of Canada (NSERC), 2018. National Science Foundation, 2020.
- Organizer
- ◇ QuICS's Workshop on Quantum Machine Learning, 09/24 - 09/28, 2018.
 - ◇ Programming Languages and Quantum Computing (PLanQC), workshop at POPL 2020.
- Guest Editor
- ◇ Special Issue on the Techniques of Programming Languages, Logic, and Formal Methods in Quantum Computing , ACM Transaction on Quantum Computing.
- Tutorials
- ◇ *An Invitation to the Intersection of Quantum Computing and Programming Languages* at the 48th ACM SIGPLAN Symposium on Principles of Programming Languages (POPL 2021).
- Travel Grants
- ◇ NSF Student Travel Grant for 2019 Annual Conference on Quantum Information Processing (QIP). Sole PI. \$10,000. NSF-CCF-1840547.
 - ◇ NSF Student Travel Grant for 2020 Annual Conference on Quantum Information Processing (QIP). Sole PI. \$25,000. NSF-CCF-1946395.

Teaching experience

- Instructor **Introduction to Quantum Information Processing (CMSC 657)**, *University of Maryland*, graduate-level CS course, Fall 2018, Fall 2019.
- Instructor **Introduction to Quantum Computation (CMSC 457)**, *University of Maryland*, undergraduate-level CS course, Spring 2018, Spring 2020.
- Instructor **Complexity Theory (CMSC 652)**, *University of Maryland*, graduate-level CS major course, Fall 2017.
- Instructor **Intermediate Data Structure (CIS 313)**, *University of Oregon*, undergraduate-level CS major course, Winter 2016, Fall 2016, Winter 2017.
- Instructor **Introduction to Quantum Information Processing (CIS 410/510)**, *University of Oregon*, undergraduate/graduate level course, Spring 2016, Spring 2017.

Publications

(The authors of papers in theoretical computer science are listed alphabetically, whereas in other fields are listed by contribution where the last is usually the corresponding author.)

Journals

- ◇ (by contribution) Tianyi Peng, Aram Harrow, Maris Ozols, and **Xiaodi Wu**, *Simulating large quantum circuits on a small quantum computer*, Physical Review Letters, 125, 150504, 2020. also available at arXiv:1904.00102.
- ◇ Shouvanik Chakrabarti, Andrew M. Childs, Tongyang Li, and **Xiaodi Wu**. *Quantum algorithms and lower bounds for convex optimization*, Quantum 4, 221 (2020).

- ◇ Tongyang Li and **Xiaodi Wu**, *Quantum query complexity of entropy estimation*, IEEE Transaction on Information Theory, Vol. 65, Issue 5, pages 2899 - 2921, May 2019. Also available at arXiv: 1710.06025.
- ◇ Aram W. Harrow, Anand Natarajan, and **Xiaodi Wu**, *Limitations of semidefinite programs for separable states and entangled games*, Communications in Mathematical Physics, Volume 366, Issue 2, pp 423–468, 2019.
- ◇ Jeongwan Haah, Aram W. Harrow, Zhengfeng Ji, **Xiaodi Wu** and Nengkun Yu, *Sample-optimal tomography of quantum states*. IEEE Transaction on Information Theory, Volume: 63, Issue: 9, pp. 5628 – 5641, 2017.
- ◇ Aram W. Harrow, Anand Natarajan, and **Xiaodi Wu**, *An improved semidefinite programming hierarchy for testing entanglement*, Communications in Mathematical Physics, Volume 352, Issue 3, pp 881–904, 2017. Also available at arXiv:1506.08834.
- ◇ Yaoyun Shi and **Xiaodi Wu**, *Epsilon-net method for optimizations over separable states*. Theoretical Computer Science, 598:51–63, 2015.
- ◇ Gus Gutoski and **Xiaodi Wu**, *Parallel approximation of min-max problems with applications to classical and quantum zero-sum games*. Computational Complexity, 22(2):385-428, 2013, the **special issue** of CCC 2012.
- ◇ (by contribution) **Xiaodi Wu** and Runyao Duan, *Exact Quantum Search by Parallel Unitary Discrimination Schemes*, Physical Review A, **78**, 012303 (2008). Selected for the July 2008 issue of Virtual Journal of Quantum Information.
- ◇ (by contribution) **Xiaodi Wu** and Gui Lu Long, *Verifier-based Algorithm for Unsorted Database Search Problem*, International Journal of Quantum Information, vol.5 no.4, pp **597 - 604** (2007).
- ◇ (by contribution) **Xiao-di Wu**, Yong-tao Huang, Xin-kun Ma, *Data processing and software realization of wave-lengths of spectrum during CCD measurement*, Experimental Technology and Management, vol.24, no.4 p**48-51** (2006).

Peer-reviewed Conferences with Published Proceedings

- ◇ (by contribution) Kesha Hietala, Robert Rand, Shih-Han Hung, **Xiaodi Wu**, and Michael Hicks, *A Verified Optimizer for Quantum Circuits*, to appear at the 48th ACM SIGPLAN Symposium on Principles of Programming Languages (POPL 2021). also available at arXiv:1912.02250.
- ◇ (by contribution) Shaopeng Zhu, Shih-han Hung, Shouvanik Chakrabarti, and **Xiaodi Wu**, *On the Principles of Differentiable Quantum Programming Languages*. In the proceedings of the 41st ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI 2020). arXiv: 2004.01122.
- ◇ (by contribution, *=equal contribution) Shouvanik Chakrabarti*, Yiming Huang*, Tongyang Li, Soheil Feizi, and **Xiaodi Wu**, *Quantum Wasserstein Generative Adversarial Networks*. In the proceedings of the 33rd Annual Conference on Neural Information Processing Systems (NeurIPS 2019).
- ◇ (by contribution) Kesha Hietala, Robert Rand, Shih-Han Hung, **Xiaodi Wu**, and Michael Hicks., *Verified Optimization in a Quantum Intermediate Representation*, extended abstract in Quantum Physics and Logic (QPL 2019), arXiv:1904.06319.
- ◇ (by contribution) Tongyang Li, Shouvanik Chakrabarti, and **Xiaodi Wu**. *Quantum algorithms for training linear and kernelized classifiers*. In the proceedings of the 36th International Conference on Machine Learning (ICML 2019). Also available at arXiv:1904.02276.

- ◇ Fernando G. S. L. Brandao, Amir Kalev, Tongyang Li, Cedric Yen-Yu Lin, Krysta M. Svore, and **Xiaodi Wu**, *Quantum SDP Solvers: Large Speed-ups, Optimality, and Applications to Quantum Learning*. In the Proceedings of the 46th International Colloquium on Automata, Languages and Programming (ICALP 2019). also available at arXiv: 1710.02581v2.
- ◇ (by contribution) Shih-Han Hung, Kesha Hietala, Shaopeng Zhu, Mingsheng Ying, Michael Hicks, and **Xiaodi Wu**. *Quantitative Robustness Analysis of Quantum Programs*. In the proceedings of the 46th ACM SIGPLAN Symposium on Principles of Programming Languages (POPL 2019). also available at arXiv: 1809.01731.
- ◇ (by contribution) Mingsheng Ying, Shenggang Ying, and **Xiaodi Wu**, *Invariants of Quantum Programs: Characterizations and Generation*. In Proceedings of the 44th ACM SIGPLAN Symposium on Principles of Programming Languages (POPL 2017).
- ◇ Jeongwan Haah, Aram W. Harrow, Zhengfeng Ji, **Xiaodi Wu** and Nengkun Yu, *Sample-optimal tomography of quantum states*. In Proceedings of the ACM 48th Annual Symposium on the Theory of Computing (STOC 2016), available at arXiv:1508.01797.
- ◇ Aram W. Harrow, Anand Natarajan, and **Xiaodi Wu**, *Tight SoS-degree bounds for approximate Nash equilibria*. In Proceedings of the Computational Complexity Conference (CCC 2016).
- ◇ Kai-Min Chung, **Xiaodi Wu**, and Henry Yuen, *Parallel repetition for entangled k -player games via fast quantum search*. In Proceedings of the Computational Complexity Conference (CCC 2015), also available at arXiv:1501.00033, 2015.
- ◇ Yaoyun Shi and **Xiaodi Wu**, *Epsilon-net method for optimizations over separable states*. In Proceedings of the 39th International Colloquium on Automata, Languages and Programming (ICALP 2012), pp. 798–809.
- ◇ Gus Gutoski and **Xiaodi Wu**, *Parallel approximation of min-max problems with applications to classical and quantum zero-sum games*. In Proceedings of the 27th Annual IEEE Conference on Computational Complexity (CCC 2012), pp. 21–31.

Peer-reviewed Conferences without Published Proceedings

- ◇ Shouvanik Chakrabarti, Andrew Childs, Shih-han Hung, Tongyang Li, Chunhao Wang, and **Xiaodi Wu**, *Quantum algorithm for estimating volumes of convex bodies*, appeared as a single-track talk at the 23rd Conference on Quantum Information Processing (QIP 2020), arXiv:1908.03903.
- ◇ Shouvanik Chakrabarti, Andrew M. Childs, Tongyang Li, and **Xiaodi Wu**. *Quantum algorithms and lower bounds for convex optimization*, at the 22th Conference on Quantum Information Processing (QIP 2019). Also available at arXiv: 1809.01731.
- ◇ Fernando G. S. L. Brandao, Amir Kalev, Tongyang Li, Cedric Yen-Yu Lin, Krysta M. Svore, and **Xiaodi Wu**, *Quantum SDP Solvers: Large Speed-ups, Optimality, and Applications to Quantum Learning*, at the 22th Conference on Quantum Information Processing (QIP 2019). Also available at arXiv:1710.02581v2.
- ◇ Yi-Hsiu Chen, Kai-Min Chung, Ching-Yi Lai, Salil P. Vadhan, and **Xiaodi Wu**, *Computational Notions of Quantum Min-Entropy*, at the 7th International Conference on Quantum Cryptography (QCrypt 2017). Also available at arXiv: 1704.07309.
- ◇ Aram W. Harrow, Anand Natarajan, and **Xiaodi Wu**, *Limitations of semidefinite programs for separable states and entangled games*, at the 20th Conference on Quantum Information Processing (QIP 2017).

- ◇ Kai-Min Chung, Yaoyun Shi, and **Xiaodi Wu**, *General randomness amplification with non-signaling security*, at the 20th Conference on Quantum Information Processing (QIP 2017).
- ◇ Jeongwan Haah, Aram W. Harrow, Zhengfeng Ji, **Xiaodi Wu** and Nengkun Yu, *Sample-optimal tomography of quantum states*, at the 19th Conference on Quantum Information Processing (QIP 2016), available at arXiv:1508.01797.
- ◇ Kai-Min Chung, Yaoyun Shi, and **Xiaodi Wu**, *Physical Randomness Extractors*, appeared as a **plenary talk** at the 17th Conference on Quantum Information Processing (QIP 2014), also available at arXiv:1402.4797v2.
- ◇ Yaoyun Shi and **Xiaodi Wu**, *Epsilon-net method for optimizations over separable states*. **Contributed talk** at the 15th Workshop on Quantum Information Processing (QIP 2012), also available at arXiv:1112.0808, 2011.
- ◇ Gus Gutoski and **Xiaodi Wu**, *Parallel approximation of min-max problems with applications to classical and quantum zero-sum games*. **Featured talk** at the 15th Workshop on Quantum Information Processing (QIP 2012), available at arXiv:1011.2787, 2010.
- ◇ Zhengfeng Ji and **Xiaodi Wu**, *Non-Identity Check Remains QMA-Complete for Short Circuits*, **contributed talk** at the 9th Asian Conference on Quantum Information Science (AQIS09), also available at arXiv:0906.5416, 2009.

Manuscripts

- ◇ (by contribution) Yuxiang Peng, Mingsheng Ying and **Xiaodi Wu**, *Algebraic Reasoning of Quantum Programs via Non-Idempotent Kleene Algebra*, manuscript, 2020.
- ◇ (by contribution) Xuchen You and **Xiaodi Wu**, *Exponentially Many Local Minima for Shallow Variational Quantum Circuits*, manuscript, 2020.
- ◇ (by contribution) Tongyang Li, Shouvanik Chakrabarti, Chunhao Wang, and **Xiaodi Wu**, *Sublinear Classical and Quantum Algorithms for Matrix Games*, manuscript, 2020.
- ◇ (by contribution) Shouvanik Chakrabarti, Chi-Ning Chou, Kai-Min Chung, and **Xiaodi Wu**, *Scalable Verification of Quantum Supremacy based on Circuit Obfuscation*, manuscript, 2020.
- ◇ Kai-Min Chung, Yi Lee, Han-Hsuan Lin, and **Xiaodi Wu**, *Constant-round Blind Classical Verification of Quantum Sampling*, manuscript, 2020.
- ◇ (by contribution) Shih-han Hung, Xin Wang, Yuxiang Peng, Shaopeng Zhu, and **Xiaodi Wu**, *On the theory and practice of invariant-based verification of quantum programs*, manuscript, 2019.
- ◇ **Xiaodi Wu**, Penghui Yao, and Henry Yuen , *Raz-McKenzie simulation with the inner product gadget*, manuscript, 2017. also available at ECCC TR17-010.
- ◇ **Xiaodi Wu** and Henry Yuen, *On the limits of communication with non-local resources*, manuscript, 2015.
- ◇ Kai-Min Chung, Xin Li, and **Xiaodi Wu**, *Multi-Source Randomness Extractors Against Quantum Side Information, and their Applications*, manuscript, also available at arXiv:1411.2315, 2014.
- ◇ Yaoyun Shi, Wei Yu, and **Xiaodi Wu**, *Limits of Quantum One-way Communication by Matrix Hypercontractive Inequalities*, manuscript, 2013.
- ◇ **Xiaodi Wu**, *Parallelized Solution to Semidefinite Programmings in Quantum Complexity Theory*, Technical Report, also available at arXiv:1009.2211, 2010.

- ◇ **Xiaodi Wu**, *Equilibrium Value Method for the proof of $QIP=PSPACE$* , manuscript, available at arXiv:1004.0264, 2010.

Invited Talks

- ◇ **How hard is it to train variational quantum circuits?**
02/2020 Simons' Quantum Algorithm Workshop, UC Berkeley.
- ◇ **Application and training of quantum generative models.**
12/2019 Q2B Practical Quantum Computing Workshop, San Jose.
- ◇ **Toward End-to-End quantum applications.**
12/2019 IQI seminar, Caltech.
12/2019 Stanford University.
11/2019 Texas Tech University.
11/2019 Quantum Computing Lecture series, Louisiana State University.
- ◇ **Provable quantum advantages for optimization and machine learning.**
05/2019 2nd IAMCS Workshop on Quantum Computation and Information, TAMU.
- ◇ **Quantum algorithms for semidefinite programs and convex optimization.**
11/2018 Capital Area Theory Day.
- ◇ **Quantum algorithms for convex optimization and leading eigenvalue computation.**
10/2018 Quantum Information Processing Seminar, MIT.
- ◇ **Quantum algorithms for semidefinite programs.**
05/2018 Workshop on "Quantum Computing & Optimization of large Power Systems", Stanford.
- ◇ **Algorithms for quantum computers.**
05/2018 CCC Workshop on Next Steps in Quantum Computing, D.C.
- ◇ **Quantum query complexity of entropy estimation.**
07/2017 Microsoft Quantum Algorithms Workshop, Redmond.
04/2017 Microsoft Research, Redmond.
- ◇ **General randomness amplification with non-signaling security.**
03/2017 IQI Seminar, Caltech.
01/2017 The 20th Workshop on Quantum Information Processing (QIP 2017).
- ◇ **Limitations of monogamy, Tsirelson-type bounds, and other semidefinite programs in quantum information.**
08/2016 QMA(2) Workshop, QUICS, University of Maryland
12/2015 IQI Seminar, Caltech
- ◇ **Device-independent Quantum Cryptography.**
02/2016 Oregon Crypto Meeting, Oregon State University
- ◇ **New Upper and Lower Bounds for Entanglement Testing.**
05/2015 Microsoft Research, Redmond.
- ◇ **Randomness Extraction in the Presence of Quantum Side Information.**
06/2015 1st Trustworthy Quantum Information Workshop, Ann Arbor, USA
05/2015 Simon's Institute for the Theory of Computing, UC Berkeley.
- ◇ **Improved Entanglement Detection with Tools from Algebraic Geometry.**
11/2014 Colloquium, Institute for Quantum Computing, University of Waterloo.
- ◇ **Multi-Source Randomness Extractors Against Quantum Side Information.**
11/2014 Theory Seminar, Virginia Commonwealth University, Richmond.

- ◇ **Physical Randomness Extractors.**
 07/2014 Gordon Research Seminar, Advances in Quantum Information Science, Stonehill College.
 03/2014 University of Michigan, Ann Arbor
 02/1014 IQI Seminar, Caltech.
- ◇ **Robust Full Randomness Extraction from Any Weak Source.**
 05/2013 Quantum Information Processing Seminar, MIT.
- ◇ **Equilibrium Value Method for Optimization Problems and its Applications in Quantum Computation.**
 04/2013 IQI Seminar, Caltech
- ◇ **Applications of Sum of Squares in Quantum Information.**
 04/2013 University of California, San Diego.
- ◇ **Epsilon-net method for optimizations over separable states.**
 07/2012 The 39th International Colloquium on Automata, Languages and Programming (ICALP'12).
 03/2012 Tsinghua University.
 12/2011 The 15th Workshop on Quantum Information Processing (QIP'12).
- ◇ **Parallel approximation of min-max problems with applications to classical and quantum zero-sum games.**
 06/2012 The 27th Annual IEEE Conference on Computational Complexity (CCC'12).
 12/2011 The 15th Workshop on Quantum Information Processing (QIP'12).