EE599 Adiabatic Quantum Computing (4 units)

Course Syllabus

Term: Fall 2015

Course Title: EE599 Adiabatic Quantum Computing

Background: Adiabatic quantum computing (AQC) is an alternative quantum computing paradigm to the more standard circuit model approach. It has generated large interest due to its intrinsic robustness to certain forms of decoherence, which has made it an attractive option towards establishing `quantum supremacy' over classical algorithms. Moreover, commercial devices are already available that implement a form of AQC known as quantum annealing that is restricted to optimization problems. Many exciting open problems remain in AQC, such as the establishment of a threshold-accuracy theorem that would allow fault-tolerant AQC, or native algorithms admitting exponential speedups.

Goals: In this class, we will provide an overview of the key ideas of AQC and provide an up-to-date overview of work in the field. The overall goal is to bring students to the forefront of current research to enable them to proceed in this active area of research. The course is aimed at graduate students and engineers who have already completed basic coursework in quantum mechanics. We begin with a review of the adiabatic theorem, followed by an overview of universal adiabatic quantum computing. We will demonstrate the equivalence to the circuit model, provide an overview of algorithms, as well as obstacles that remain to be overcome in AQC. We will focus on Adiabatic Quantum Optimization and Quantum Annealing, an area where commercial quantum devices are already available. Students will gain hand-on experience programming the D-Wave quantum annealing device housed at the USC-Lockheed Martin Quantum Computing Center.

Instructor:

Tameem Albash
Information Science Institute
University of Southern California
Marina del Rey, CA 90292
E-mail: albash@usc.edu

Lecture: MW 10-11:50

Office hours: TBD

Grading: In class participation (20%), Homework (40%), Final presentation (40%)

Pre-requisites: Graduate level course in quantum mechanics

Textbook: No required textbook. The reference material (see below for a partial list) is available on the arXiv.

Tentative Schedule:
Week 1: Introduction and Landau-Zener transitions

Week 2: The ‘A’ in AQC: The Adiabatic Theorem
Week 3-4: The ‘QC’ in AQC: QMA-completeness and gadgets for simulating high-weight operators
Week 5: Equivalence to the circuit model
Week 6-7: AQC in an Open Quantum World
Week 8-9: Adiabatic Quantum Optimization (AQO) and Quantum Annealing
Week 10-11: Quantum speedup (or lack thereof) in AQC/AQO
Week 12: Quantum error correction for AQC /AQO
Week 13-14: Quantum Annealing on the D-Wave Processors
Week 15: Project Discussions and Presentations

References

[1] A Quantum Adiabatic Evolution Algorithm Applied to Random Instances of an NP-Complete Problem. Edward Farhi, Jeffrey Goldstone, Sam Gutmann, Joshua Lapan, Andrew Lundgren, Daniel Preda, Science 20 April 2001, Vol. 292 no. 5516 pp. 472-475. quant-ph/0104129.

[2] 3-Local Hamiltonian is QMA-complete, Julia Kempe, Oded Regev. Quantum Computation and Information, Vol. 3(3), p. 258-64, 2003. quant-ph/030207.

[3] The Complexity of the Local Hamiltonian Problem, Julia Kempe, Alexei Kitaev, Oded Regev. SIAM Journal of Computing, Vol. 35(5), p. 1070-1097 (2006), conference version in Proc. 24th FSTTCS, p. 372-383 (2004). quant-ph/0406180.

[4] Realizable Hamiltonians for Universal Adiabatic Quantum Computers, Jacob D. Biamonte, Peter J. Love. Phys. Rev. A 78, 012352 (2008). arXiv:0704.1287.

[5] Adiabatic Quantum Computation is Equivalent to Standard Quantum Computation, Dorit Aharonov, Wim van Dam, Julia Kempe, Zeph Landau, Seth Lloyd, Oded Regev. SIAM Journal of Computing, Vol. 37, Issue 1, p. 166-194 (2007), conference version in Proc. 45th FOCS, p. 42-51 (2004). quant-ph/0405098.

[6] Simple proof of equivalence between adiabatic quantum computation and the circuit model, Ari Mizel, Daniel A. Lidar, Morgan Mitchell. Phys. Rev. Lett. 99, 070502 (2007). quant-ph/0609067.

[7] Gadgets for simulating high-weight operators, Perturbative Gadgets at Arbitrary Orders. Stephen P. Jordan, Edward Farhi. Phys. Rev. A 77, 062329 (2008). arXiv:0802.1874.

[8] Quantum Search by Local Adiabatic Evolution, Jeremie Roland, Nicolas J. Cerf. Phys. Rev. A 65, 042308 (2002). quant-ph/0107015.

[9] Continuous-Time Quantum Algorithms for Unstructured Problem. Itay Hen. J. Phys. A: Math. Theor. 47 045305 (2014). arXiv:1302.7256.

[10] How Powerful is Adiabatic Quantum Computation? Wim van Dam, Michele Mosca, Umesh Vazirani. Proceedings of the 42nd Annual Symposium on Foundations of Computer Science, pp. 279-287 (2001). quant-ph/0206003.

[11] How detrimental is decoherence in adiabatic quantum computation? Tameem Albash, Daniel A. Lidar. arXiv:1503.08767.

[12] Adiabatic quantum optimization with the wrong Hamiltonian. Kevin C. Young, Robin Blume-Kohout, Daniel A. Lidar. Phys. Rev. A 88, 062314 (2013). arXiv:1310.0529.

[13] Error suppression and error correction in adiabatic quantum computation I: techniques and challenges. Kevin C. Young, Mohan Sarovar, Robin Blume-Kohout. Phys. Rev. X 3, 041013 (2013) arXiv:1307.5893.

Statement for Students with Disabilities:

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible.

DSP is located in STU 301 and is open 8:30 A.M.-5:00 P.M., Monday through Friday. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX), ability@usc.edu (email).

Statement on Academic Integrity:

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect ones own academic work from misuse by others as well as to avoid using anothers work as ones own. All students are expected to understand and abide by these principles. SCampus, the Student Guidebook, (scampus.usc.edu) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A.

Emergency Preparedness/Course Continuity in a Crisis:

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.