Software Engineering II Research Projects

Quantum Computing Projects: RP5.1 - RP5.3 - RP5.4 - RP5.5

Politecnico di Milano

November 29, 2021

Author:
Francesco Piro
francesco.piro@mail.polimi.it

Focusing References

- The NISQ era [Preskill, 2018]
- The Quantum Algorithm Zoo
  `https://quantumalgorithmzoo.org/`
- An Introduction to Quantum Computing without the Physics [Nannicini, 2020]
- Quantum Algorithms [Cleve et al., 1998]
- Reference to last year repository
  `https://github.com/Askarpour/sw2_quantum_research`

- Quantum Computation and Quantum Information [Nielsen and Chuang, 2002]
- Qiskit Library `https://github.com/Qiskit`
- Qiskit TextBook `https://qiskit.org/textbook/preface.html`
- IBM Quantum Experience `https://quantum-computing.ibm.com/`

Quantum Annealing Model

- Quantum Annealing [Johnson, 2011]
- Quantum Annealing in the tranverse Ising model [Kadowaki and Nishimori, 1998]
- Quantum Annealing mathematical foundations [Morita and Nishimori, 2008]
- Ising Formulations of many NP Problems [Lucas, 2014]
- D-Wave Ocean Software Development Kit `https://github.com/dwavesystems`
- D-Wave Leap and Documentation `https://www.dwavesys.com/solutions-and-products/cloud-platform/`, `https://docs.dwavesys.com/docs/latest/index.html`

State of the art Analysis

- Quantum Computing Tools `https://quantumcomputingreport.com/resources/tools/`
- IEEE Quantum Week `https://qce.quantum.ieee.org/`
- Quantum Machine Intelligence journal `https://www.springer.com/journal/42484`

Consider as a good starting points also the references reported in the first three slides

The Gate and the Annealing Quantum Models

- Computational Equivalence [Mizel et al., 2007]
- Quantum vs Classical Simulated Annealing [Crosson and Harrow, 2016]

Choice of the Algorithm

- In general you could choose any problem you want
- Balanced k-means Clustering on AQC [Arthur et al., 2021]
- Optimization Problems from [Glover et al., 2019]
- ...

Consider as a good starting points also the references reported in the first three slides

Implementation of a Quantum Annealing Algorithm

- Quantum Bridge Analytics [Glover et al., 2019]
  - Max-Cut
  - Minimum Vertex Cover (MVC)
  - Set Packing
  - Set Partitioning
  - Graph Coloring
  - Quadratic Assignment
  - Quadratic Knapsack
  - Section 6 for Machine Learning Applications
- Notebooks from D-Wave Leap
  `https://cloud.dwavesys.com/leap/resources#demos`

Consider the references in the slide of the quantum annealing model

Quantum Natural Language Processing

- pytket library from Cambridge Quantum `https://github.com/CQCL/pytket`
- lambeq toolkit for QNLP `https://github.com/CQCL/lambeq`
- Accompanying paper to lambeq [Kartsaklis et al., 2021]
- QNLP examples `https://github.com/CQCL/lambeq/blob/main/docs/examples/`

Consider the references in the slide of the gate model

Arthur, D. et al. (2021).
Balanced k-means clustering on an adiabatic quantum computer.
Quantum Information Processing, 20(9):1–30.

Cleve, R., Ekert, A., Macchiavello, C., and Mosca, M. (1998).
Quantum algorithms revisited.
Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences, 454(1969):339–354.

Crosson, E. and Harrow, A. W. (2016).
Simulated quantum annealing can be exponentially faster than classical simulated annealing.
In *2016 IEEE 57th Annual Symposium on Foundations of Computer Science (FOCS)*, pages 714–723. IEEE.

Glover, F., Kochenberger, G., and Du, Y. (2019).
Quantum bridge analytics: a tutorial on formulating and using qubo models.
4OR, 17(4):335–371.

Johnson, e. a. (2011).
Quantum annealing with manufactured spins.
Nature, 473(7346):194–198.

Kadowaki, T. and Nishimori, H. (1998).
Quantum annealing in the transverse ising model.
Physical Review E, 58(5):5355.

Kartsaklis, D., Fan, I., Yeung, R., Pearson, A., Lorenz, R., Toumi, A., de Felice, G., Meichanetzidis, K., Clark, S., and Coecke, B. (2021).
lambeq: An Efficient High-Level Python Library for Quantum NLP.
arXiv preprint arXiv:2110.04236.

Lucas, A. (2014).
Ising formulations of many np problems.
Frontiers in physics, 2:5.

Mizel, A., Lidar, D. A., and Mitchell, M. (2007).
Simple proof of equivalence between adiabatic quantum computation and the circuit model.
Physical review letters, 99(7):070502.

Morita, S. and Nishimori, H. (2008).
Mathematical foundation of quantum annealing.
Journal of Mathematical Physics, 49(12):125210.

Nannicini, G. (2020).
An introduction to quantum computing, without the physics.
SIAM Review, 62(4):936–981.

Nielsen, M. A. and Chuang, I. (2002).
Quantum computation and quantum information.

Preskill, J. (2018).
Quantum computing in the nisq era and beyond.
Quantum, 2:79.