Adiabatic Quantum Computation

at D-Wave Systems Inc.

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Computer Science
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MA 591 Special Topics in Quantum Computation

Outline

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Adiabatic Theorem

Max Born and Vladimir Fock (1928)

A physical system remains in its instantaneous eigenstate if a given perturbation is acting on it slowly enough and if there is a gap between the eigenvalue and the rest of the Hamiltonian's spectrum.

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Application

- Start with $|\psi(0)\rangle$ as the ground state of $\mathcal{H}(0)$.
- Quantum systems evolve according to the Schrödinger equation.

$$i\frac{d}{dt}|\psi(t)\rangle = \mathcal{H}(t)|\psi(t)\rangle$$

- If there is a non-zero gap between $|\psi(0)\rangle$, the ground state, and the next lowest energy level as long as $\mathcal{H}(t)$ varies slowly enough (i.e. little energy is added to the system) $|\psi(t)\rangle$ will remain close to the instantaneous ground state of $\mathcal{H}(t)$.

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The Magic

- Encode the solution in the ground state of a problem Hamiltonian $\mathcal{H}_P$.
  - Specifying $\mathcal{H}_P$ is easy but finding its ground state is difficult.
- Choose an initial Hamiltonian $\mathcal{H}_B$ whose ground state is easy to find.
- Construct the system:

$$\mathcal{H}(t) = (1 - t/T)\mathcal{H}_B + (t/T)\mathcal{H}_P$$

Where T is a parameter to control the rate at which $\mathcal{H}(t)$ varies. Normalized to $\tilde{\mathcal{H}}(s), 0 \leq s \leq 1$:

$$\tilde{\mathcal{H}}(s) = (1 - s)\mathcal{H}_B + s\mathcal{H}_P$$

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History

- Founded in 1999 by:
  - Haig Farris
  - Geordie Rose (CTO)
  - Bob Wiens (former CFO)
  - Alexandre Zagoskin (Chief Scientist)
- Started as an off-shoot of the University of British Columbia funding academic research in quantum computing.
- Currently located in Burnaby, British Columbia.

Goals

- Find low cost solutions to Quadratic Unconstrained Binary Optimization (QUBO) problems.
  - arXiv:quant-ph/0001106v1 3-SAT
  - NPC controversy
- Equivalent to finding low energy states of classical Ising Hamiltonian:

$$\mathcal{H} = \sum_i h_i \sigma_{zi} + \sum_{ij} J_{ij} \sigma_{zi} \sigma_{zj}$$

Goals

You can create overlays...

- using the `pause` command:
  - First item.
  - Second item.
- using overlay specifications:
  - First item.
  - Second item.
- using the general `uncover` command:
  - First item.
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Summary

- The first main message of your talk in one or two lines.
- The second main message of your talk in one or two lines.
- Perhaps a third message, but not more than that.

- Outlook
  - Something you haven't solved.
  - Something else you haven't solved.

For Further Reading I


A. Author.
Handbook of Everything.
Some Press, 1990.


S. Someone.
On this and that.
Journal of This and That, 2(1):50–100, 2000.