Quantum Technology

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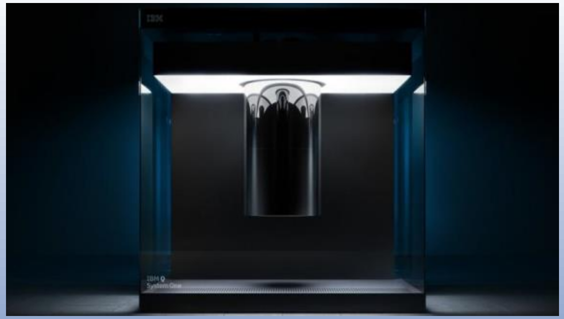
28-01-2025

Quantum Computation and QUBO models

Three possible roads to quantum computing:



Gate Based Quantum Computing

- The ultimate goal of quantum computing
- Promises exponential improvement
- Hardware still in the early stages

Quantum Annealing

- Fewer vendors are supplying this hardware
- Brings advantage to a very specific set of problems
- More mature hardware, good for optimization, algorithms are used in production

Quantum Inspired Optimization

- Classical hardware simulates quantum annealing
- Exploits the maturity of classical hardware and cleverness of quantum algorithms
- Ready for use

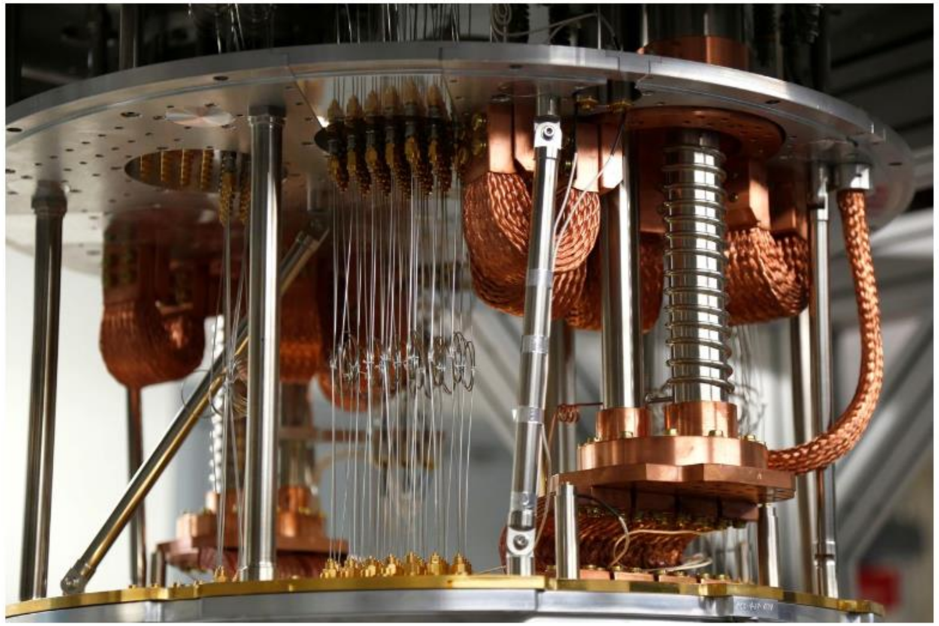
	Gate Based Quantum Computing	Quantum Annealing	Quantum Inspired Optimization
	Quantum	Hybrid between classical and quantum	Classical
Problem formulation	QUBO	QUBO	QUBO
Technical solution	QAOA	Embedding the problem on special purpose quantum devices	6 solvers available

Quantum computing has changed the way we solve optimisation problem

THE WALL STREET JOURNAL.

Financial Firms Seek Edge in Algorithms Inspired by Quantum Computing

Some firms are running algorithms used for quantum computers on advanced machines for risk analysis and portfolio optimization



Applications of quantum-inspired optimization problems can yield solutions anywhere from

10%+ accurate solutions anywhere from 2-40 times as fast

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Quantum Annealers solve QUBO optimization problems

Quantum Annealing
Quantum Inspired Optimization

Quadratic

Unconstrained

Binary

Optimization

Our goal is to minimize f

$$f(x) = \sum_{i<j}^{N} Q_{i,j} x_i x_j + \sum_{i}^{N} Q_{i,i} x_i$$

where x_i are binary variables ($x_i \in \{0,1\}$)

and $Q_{i,j}$ are the coefficients ($Q_{i,j} \in \mathbb{R}$)

Formulating a problem as a QUBO requires translation

- Our goal is to **”translate”** our problem to a model that is understandable by the solver.
- This process is called **reduction**.
- Whenever we perform a reduction we need to consider the **cost** of this reduction.

Some vocabulary with an example

$$\text{Minimize} \boxed{\boxed{\theta_0 \sum_i (-\alpha_i E(R_i))} + \boxed{\theta_1 \sum_i \sum_j \alpha_i \alpha_j \mathrm{Cov}(R_i, R_j)} + \boxed{\theta_2 \left(\sum_i \alpha_i A_i - B \right)^2}}$$

This is a QUBO model for Portfolio Optimization

- The **Objective function** describes what we want to minimize
- The **Expected return** is modelled in the green part
- The **Diversification** is modelled in the purple part
- The **Budget constraint** is modelled in the grey part
- The $\boldsymbol{\theta' s}$ are the **weights** that can be tuned based on our goal
- The $\boldsymbol{\alpha_i}$ are our **binary variables** which decide whether to 'pick' or 'not pick' a given stock
- **B** is our budget, $\boldsymbol{A_i}$ the cost of stock i, $\boldsymbol{E(R_i)}$ is the expected return of stock i of each stock and **Cov**$\boldsymbol{(R_i, R_j)}$ is the covariance between stock i and stock j

Note: The elements in blue are in general for all QUBO's the others are specific for this model

02

Introduction to the case

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Infrastructure Coverage

- **Problem:**
  - You are given a set of Antennas and need to choose a minimum number (k) of Antennas that cover a given area at least x%

- **Assumptions:**
  - You can model the area as a square grid
  - Each part of the area has equal value
  - All antennas have the same cost