QUANTUM APPROXIMATE OPTIMIZATION ALGORITHM

WHAT IS QAOA?

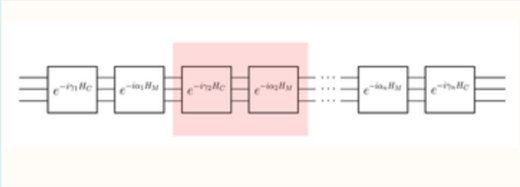


Fig.1. Sample QAOA ansatz for a three qubit circuit

The Quantum Approximate Optimization Algorithm (QAOA) is a hybrid quantum-classical algorithm designed to solve combinatorial optimization problems. It leverages quantum mechanics to approximate solutions to problems that are computationally hard for classical computers.

QAOA is a promising algorithm for near-term quantum computers, offering a way to tackle optimization problems with potential quantum advantage.

HOW DOES IT WORK?

QAOA prepares a quantum state with alternating problem and mixer operations, tuned by a classical optimizer. By repeatedly measuring and adjusting, it finds approximate solutions to problems like scheduling or network design, making it useful for near-term quantum computers.

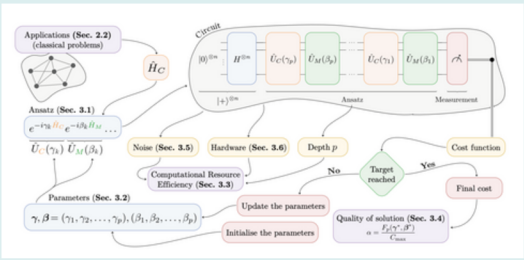


Fig.2. General scheme of QAOA and its features

WHY WE NEED IT?

QAOA bridges classical optimization & quantum computing, solving NP-hard problems faster for logistics, finance, and AI. It's NISQ-friendly, offering quantum advantage where classical methods struggle.

- **MAX CUT PROBLEM**

  Max-Cut divides graph nodes into two groups to maximize edges between them. NP-hard problem used in optimization and QAOA.

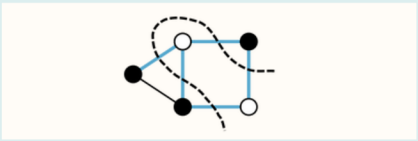


Fig.3 An example of a maximum cut

- **TRAVELING SALESMAN PROBLEM (TSP)**

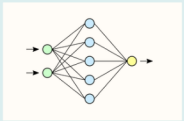
  TSP is a classic example of an optimization problem that has numerous real-world applications.

- **BOOLEAN SATISFIABILITY (SAT)**

  SAT checks if a logic formula can be true. Core to CS, NP-complete.

REAL-WORLD APPLICATIONS

QAOA solves complex optimization problems faster than classical methods in some cases, making it valuable for industries needing efficient solutions.QAOA's real-world applications include:


- Optimizing logistics (delivery routes, supply chains)
- Financial modeling (portfolio optimization, risk analysis)
- Network design (5G, power grids, traffic flow)
- Drug discovery (molecular modeling, protein folding)
- AI training (neural network optimization)

ADVANTAGES

- Hybrid approach (quantum + classical) makes it suitable for near-term quantum devices (NISQ era).
- Can outperform classical heuristics for certain problems.
- Flexible framework applicable to many optimization problems.

LIMITATIONS

- Performance depends on the choice of ansatz and optimizer.
- May require many layers (pp) for high-quality solutions, increasing circuit depth.
- Susceptible to noise in current quantum hardware.

REFERENCES

1. Wikipedia contributors. (2025, March 29). Quantum optimization algorithms. Wikipedia. https://en.wikipedia.org/wiki/Quantum_optimization_algorithms

2. Blekos, K., Brand, D., Ceschini, A., Chou, C., Li, R., Pandya, K., & Summer, A. (2024). A review on Quantum Approximate Optimization Algorithm and its variants. Physics Reports, 1068, 1–66. https://doi.org/10.1016/j.physrep.2024.03.002

3. File:QAOAcircuit.png - Wikimedia Commons, 2020c

4. File:202202 Protein colored.svg - Wikimedia Commons, 2022

5. File:201707 Medicine Capsules blue.svg - Wikimedia Commons, 2017

6. File:Max-cut.svg - Wikimedia Commons, 2009