Quantum Approximate Optimisation Algorithms for Real World Scenarios --- Strangeworks

Team: Jumpstart Quantum (David Liu, Jiaqi Guo, Yiping Wang)

Problem Statement

Background:

The quantum approximation algorithm (QAOA) is the most studied gate model approach for solving combinatorial optimization problems on noisy intermediate-scale quantum (NISQ) devices

Applications: supply chain optimization, vehicle routing, semiconductor chip design, product or financial asset portfolio optimization .

Challenge:

--- Quantum circuits depth p for optimal solutions vs. limited coherence time of current NIST devices

--- initialization of variational parameters (β, γ) and p values

--- how to determine the appropriate depth p to reduce cost and scale the optimization problem size.

Solution & Approach

Qiskit quantum computer simulators	Depth p	# shots	Top Pertange Quantum Outputs Averaged as input to classical optimizer
Ideal	1 - 8	100 to 700	100 % 20%
Noisy	1 -8	100 to 700	100 % 20 %

QAOA Optimization

Warm Start
uses a continuous-value relaxation that is positive and semi-defined to relax a convex quadratic program and find an optimal initial starting point for QAOA. Warm-start QAOA has been shown to have a higher probability of sampling the optima solution.

Select Initial values
The QAOA algorithms very reliant on finding appropriate angles that favour good partitions and causes bad partitions to destructively interfere. One of the main obstacles to overcome is determining those optimal angles efficiently.

Implication & Scaling

Several ways to scale QAOA to solve larger optimization problem with the current NISQ computers with limited qubits and quantum circuits.

QAOA-in-QAOA
applying divide-and-conquer heristics to seek the solution of subgroups in parallel and then merge theses solutions to obtain the global solution. Under different graph-setting, this algorithm is reported attaining a competitive or even better performance over the best known classical algorithms when the node count is around 2000.

David-and-Cinquer QAOA (DC-QAOA)
partitions a arger graph recursively into smaller ones whose solutions are obtained with small-size NISQ quantum computers. DC-QAOA achieves 97.14% approximation ratio (20.32% higher than classical counterpart and 94,79% expectation value (15.80 percent hito higher than quantum annealing). DC-QAOA also reduces the time complexity of covertional QAOA from exponential to quadratic.

Grover Mixers QAOA (GM-QAOA)
uses Grover-like selective phase shift mixing operators to efficiently prepare an equal superposition of all feasible solutions. It is not susceptible to Hamiltonian simulation error. Solutions with the same optimization value are always sampled with the same amplitude.