Instance Space Analysis on Quantum Algorithms

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25/07/2020

Background

- Developing a framework to robustly evaluate quantum algorithms using Instance Space Analysis
- Explore the tools needed to develop Quantum Algorithms:
  - Adiabatic Quantum Algorithms (year 1)
  - Universal Gate Based Quantum Algorithms (year 2)
- Other things:
  - System to scale experiments
  - 2 talks with the MATILDA group on my work
  - ADF Project and Exhibition in Brisbane for QAOA and VRP

Optimisation Problems

- Constraint Satisfaction (3SAT)
- Traveling Sales Person (TSP)
- Vehicle Routing (VRP)

Quantum Performance

- How do we evaluate success when analysing quantum algorithms?
  - Classical Performance vs Quantum Performance
  - Comparing different Quantum Algorithms
  - Minimising the use of quantum resource to achieve a certain success probability

Solving Optimisation Problems using a Quantum Computer

- Different Quantum Algorithms explored:
    - Adiabatic Quantum Computing (Quantum Annealing)
    - Quantum Approximate Optimisation Algorithm (QAOA)
    - Variational Quantum Eigensolver (VQE)

Quantum Algorithms

- AQC developed an implementation to simulate using `R`
- QAOA leveraging IBM `qiskit` – a Python package
- VQE leveraging IBM `qiskit`
- Using Matrix-Product states (MPS) to reduce memory burden

Example VRP Instance

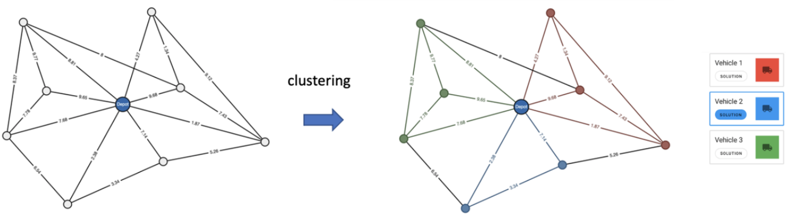


Figure 1: VRP

Example VRP problem formulated with QAOA

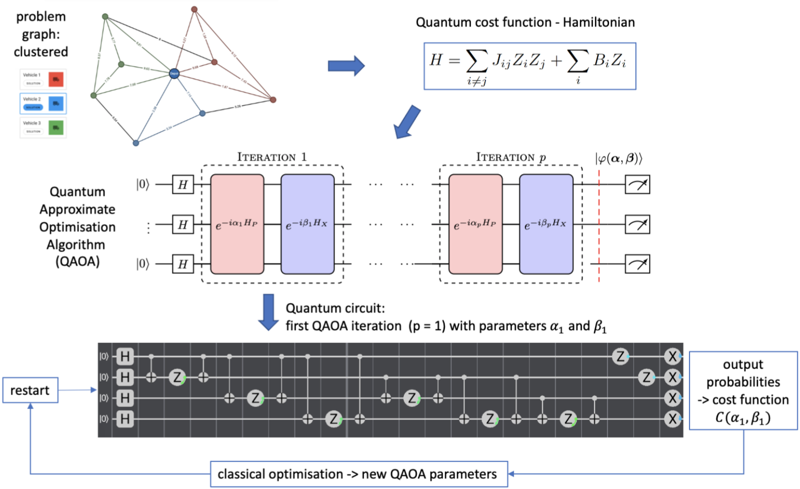


Figure 2: QAOA VRP

Types of instances investigated

- Complete random graphs
- Watts-strotgatz
- Euclidean TSPs
- Euclidean TSPs with outliers
- Asymettric TSPs

Graph Features

Graph Based Features	Boolean Features
Average Distance	Bipartite
Clique Number	Connected
Algebraic Connectivity	Acyclic
Diameter	Eulerian
Edge Connectivity	Regularity
Vertex Connectivity	Planar
Maximum Node Degree	**Laplacian (Spectral Features)**
Minimum Node Degree	Largest Eigenvalue
Cardinality of minimal dominating set	Laplacian Second Largest Eigenvalue
Number of Components	Smallest Eigenvalue
Number of vertices	
Radius	

Figure 3: Graph Features

TSP Features

TSP Features
NND Vertices
NND Coefficient Variance
Radius
Mean
Fractional Distinct Distances
Clustering Coefficient Variance
Symmetric
Asymmetry Matrix Mean

Results

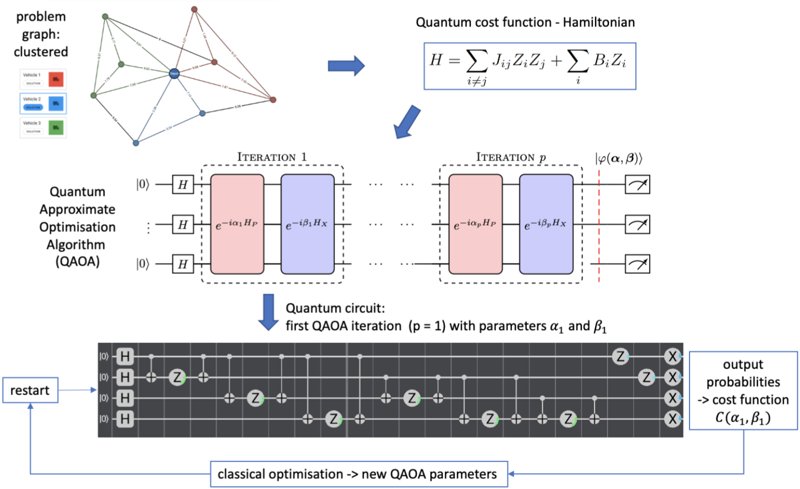
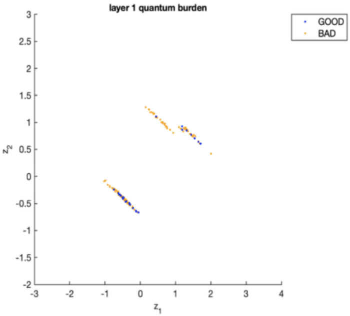


Figure 5: QAOA VRP

Results



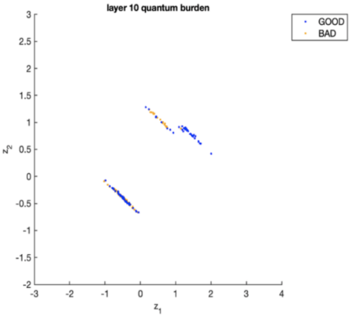


Figure 6: QAOA VRP

Thesis Outline

- Thesis Structure
  - Introduction
  - Solving Optimisation Problems using a Quantum Computer
  - Features and Algorithm Performance of Quantum Algorithms
  - Instance Space Analysis
  - Frameworks for Evaulating Quantum Algorithms / Discussion
  - Evaulation of Other Optimisation Algorithms
  - Conclusion

Discuss thesis outline

- Here is a link to the thesis outline

Any Questions?