

Hybrid Quantum Strategy Search for the Graph Domination Game

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Thursday 1st October 2026



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Acknowledgements

- EPSRC for funding this research
- SparQ for providing the quantum hardware access for this work to be possible
- Joshua Tucker and the other members of the Kent “Qiskit” Club for useful discussions
- Collaborators: Jorge Quintanilla, Paul Strange, Alex Freitas & Peter Drmota

Hybrid Algorithms

- You've already heard how graph based local games can hold advantage when players have access to quantum shared resources.¹²
- Hybrid algorithms provide a possible route to quantum utility.
- We show a new hybrid algorithm designed to find quantum advantage in these mobile agent games.

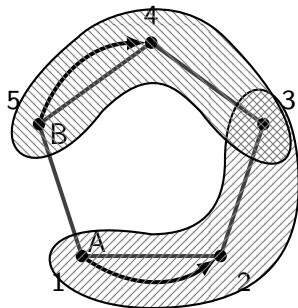
¹F. Ferreira da Silva and S. Wehner. 2025.

²J. Tucker et al 2024 New J. Phys. **26** 093038

The Graph Domination Game

Graph Domination Game

- Domination game³ is composed by:
 - Alice and Bob are placed randomly on graph
 - Each are allowed to make one move along edge
 - Both are allowed to choose different strategies - Player Asymmetric
 - Goal is to coordinate to maximise nodes dominated



³Viola, G. & Mironowicz, Phys. Rev. A 109, 042201. (4 Apr. 2024)

Initial Results

Optimal Strategies - Theory⁴

- Create function of 10 angles, one for each site per player.
- Optimized function numerically then confirmed analytically.
- One set of optimal angles are:

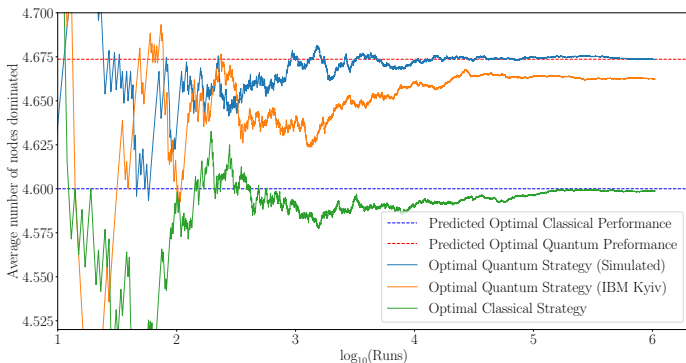
	Site 1	Site 2	Site 3	Site 4	Site 5
Alice	0	1.257	2.513	3.770	5.027
Bob	3.142	4.398	5.655	0.628	1.885

- This gives an 18.4% advantage, defined as $\frac{Q-R}{C-R} - 1$.

⁴C. Weeks et al 2026 New J. Phys. **28** 074501

Optimal Strategies - NISQ Hardware⁴

- Test optimal strategy on hardware against simulation



⁴C. Weeks et al 2026 New J. Phys. **28** 074501

Hybrid Algorithm

Hybrid Algorithms

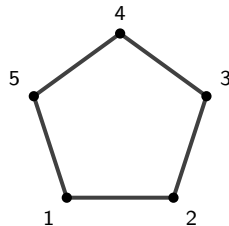
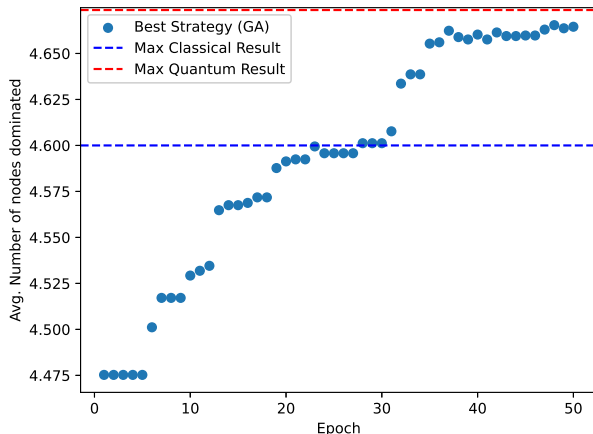
Why Use a Genetic Algorithm?

- While we can find strategies for simple graphs numerically, this becomes difficult for more complex graphs
- Look for a heuristic method to find these strategies, such as a Genetic Algorithm (GA)

GA Process

- Initialization
- Evaluation
- Create next generation population
 - Selection
 - Mating - Single Point Crossover
 - Mutation
 - Repeated until new population is full
- Repeat for each generation

Performance of Hybrid Algorithm - Simulations



- On simulations, the GA is successful in finding a solution for C_5 in 37 generations
- Bounds found in Viola & Mironowicz 2024

Reality of running Hybrid Algorithm on real quantum hardware

Using a GA is costly, the number of times you need to run the evaluation function is:

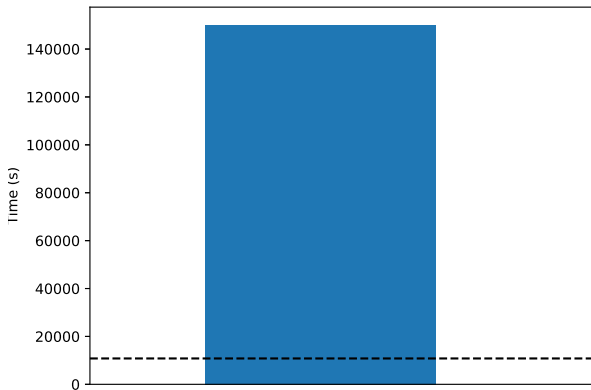
$$N = GP$$

where G is the number of generations you run the GA for and P is the size of the population.

- GA took 1250 evaluations to reliably find solution
- Fine on simulations
- Problem on real hardware, where run time matters

Reducing the run time on quantum hardware

To make the GA feasible to run using a quantum computer it needs to run in under three hours = 10800s



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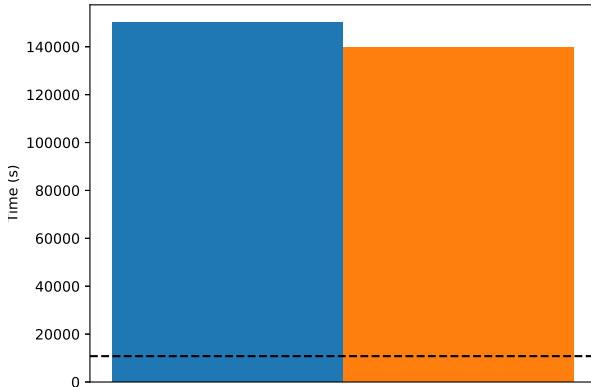
There are two main ways to reduce the run time required:

- Reduce the time each run of the function takes
- Reduce the number of times we call the function

Reducing number of calls

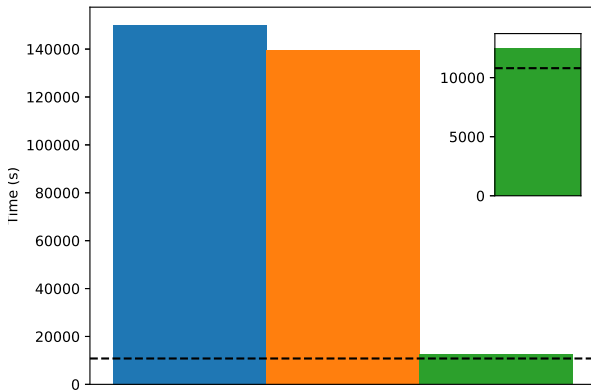
We can reduce the number of calls by re-using evaluated genomes if they appear again.

This reduces the number of calls by 7%



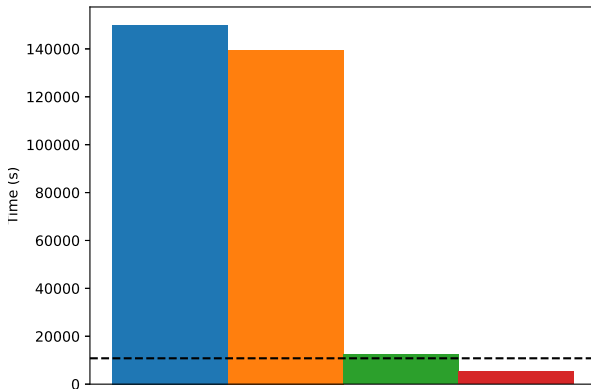
Reducing number of calls

By implementing coarse-graining, we are just above the maximum feasible running time



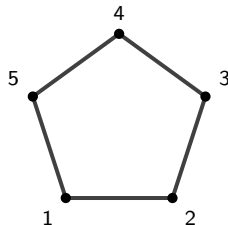
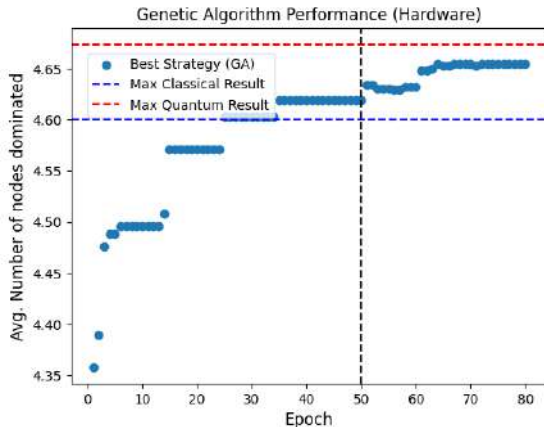
Reduce runtime for evaluation function

- Reduce the number of measurements we take for each site combination.
- Cut the run time for a single evaluation from 120 seconds to 51 seconds.



Performance of Hybrid Algorithm - NISQ Hardware

- The GA finds a strategy that beats the optimal classical within 50 generations.
- We can loosen the coarse graining to further refine advantage



Conclusion

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- We found an implementable way to realise the quantum advantage shown to exist on C_5
- We have developed a hybrid algorithm to find advantage in quantum assisted coordination problems
- we show the importance of reducing the calls to a quantum processor for such hybrid algorithms

Thank you for listening!