Quantum algorithms for mathematical optimization

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Summary

• Current activity in QIC
• What is mathematical optimization?
• Quantum algorithms for mathematical optimization
• A new approach for quantum optimization
Current research in QIC

• Quantum search algorithms, with Rafael Cação and LNCC
• Quantum gradient, with Lucas Cortez and Macquarie University
• Quantum walk, with LNCC
Current research on QIC

• Quantum computational chemistry, with Prof. Jorge Morales

• QIC education, with Profs. Beth Thacker, Yuanlin Zhang, and Jianlan Wang
On the top of that… QIC

• graduate classes
• seminar series
What is an optimization problem?

In short, it is the problem of finding the maximum or minimum of a function $f : D \rightarrow \mathbb{R}$ over a subset $S$ of its domain, i.e.

$$\text{maximize } f (x)$$

$$\text{s.t. } x \in S$$
Are optimization problems relevant?

“Nothing in all the world will occur in which no maximum or minimum rule is somehow shining forth” Leonhard Euler
Optimization problems appear in

- Manufacturing
- Aviation
- Sports
- Medical sciences
- Finance
- Telecommunications
- Mathematics, physics, chemistry, biology, computer science, etc.
QIC in industry

Emphasis on:

• NISQ approach to computational chemistry
• Quantum algorithms for solving mathematical optimization application models
Quantum algorithms for mathematical optimization

• Grover search for finding the maximum
• QAOA and the adiabatic approach
• Quantum algorithms for:
  – Gradient descent
  – Linear programming
Computational complexity

• For the most part, *convex* optimization problems are solvable in polytime
• The vast majority of optimization models arising in real-life applications are NP-hard
• The state-of-the-art consists in solving such models by solving a sequence of convex relaxations... and here’s where QIC makes a difference
A new approach

Quantum walk to speed up convex optimization problems. Specifically:

• Use the quantum walk to speed up mixing in the Markov chain of the problem
• Perform sampling and search to obtain approximate optima with high probability.
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