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Introduction

This document constitutes the report that accompanies our code, for the 2021 IEEE quantum computing Hackathon. The code can be found at the following URL.

Motivation

The COVID-19 pandemic introduced a set of novel challenges to the international community. Life-saving efforts include: hospital readiness improvements, vaccinations, accelerated R&D initiatives, and lock-downs of cities and countries. These lock-downs have been sometimes for non-essential activities only, with varying degrees of strictness. But it behooves us to examine in detail the benefits associated with locking down a locale, weighed against the costs of the same. For example, if a city is a supplier of medical equipment is locked down, then this negatively impacts supply chains serving to alleviate the very problem implicated by the lockdown. Furthermore, long-term economic harm will have its own inevitable public health toll. This work is not intended to comment on the public discussion of these values, but simply to explore consequences quantitatively, as a service to the discussion.

We propose to assess an optimal means of restricting two cities from interacting via travel and freight, by modeling cities as nodes in a graph, and implementing a QAOA algorithm to determine the solution to a MaxCut problem on a quantum computer simulator.

Innovation

The use of MaxCut problems for logistics problems is well-established. The originality of the current work stems from the use of competing contributions to the weight of each individual edge in the graph. Instead of minimizing or maximizing, or indeed even maximizing subject to constraints, we are simultaneously minimizing the impact to supply chains and maximizing the benefits to global health via e.g. reducing COVID-19 transmission. Furthermore, additional directions have value as original contributions. For example, by including the impact of shutting down centers that supply health equipment could be modeled using advanced methods like machine learning – and these methods themselves could also be done on quantum computers using QAOA. This allows for very sensitive adjustments to be done to the overall cost-benefit analysis done by policy-makers and legislatures.

Applicability

We estimate that the code could be applicable in a matter of months, for small networks of cities. The steps to application include:

1. Acquiring more realistic data. Our current dataset is toy data, meant only to indicate applicability. Real-world data should be gathered to assess usability.

2. Running more cities on larger quantum circuits. We have restricted ourselves to only a handful of cities, but the strength of quantum computing lies in cases where N is large, which in turn necessitates larger circuits.
3. More realistic functional relationships between data and overall impacts on supply chains and COVID-19 transmission. This could be an ongoing study, since there is a rich opportunity for data mining here, and traditional data science in its own right.

The Qiskit Runtime

Our code includes QAOA implementations that do not use the runtime, as well as an implementation that does. It can be seen from the code that the use of the runtime drastically lowers the amount of code, easing maintenance. Also, as with all QAOA algorithms, the communication between the QPU and classical computing resources are critical. As the runtime matures, this will make the runtime all the more important.

Future Applications

The general principle of weighting a graph with competing interests – some positive and some negative – has a great deal of application. As discussed, the means of assigning the weights can be expanded to include many advanced techniques, with a corresponding increase in the discriminating power of the resulting MaxCut solution. Likewise, other competing interests could be added other than simply health-based and economic. This makes the overall method a very general way of finding optimal divisions in global commerce.

Technology Stack and Design Decisions

We chose to use Jupyter notebooks, for ease of use. The same content could easily be scripted and/or used as executable code. It would require minimal work to accomplish this.

The substantive design decisions are primarily about the functional relationships between the data various city parameters and the overall impact on COVID-19 transmission or supply chain disruption. These functional relationships are merely illustrative at this point. They cannot be considered realistic. We made this decision both because of time constraints – it is a very open-ended problem to determine realistic relationships – and because it seems orthogonal to the goal of proving the concept.