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Improving adoption of quantum vector annealing in supply chains

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Abstract: Quantum annealing, a maturing technology, offers a potential solution to large scale combinatorial optimization problems by leveraging quantum bits (qubits) in superposition to explore vast solution spaces simultaneously, significantly reducing computation time. Currently, quantum annealers can handle up to 11,000 binary variables, with hybrid solvers capable of addressing problems with up to 1 million binary variables. Though not yet consistently optimal, these approaches provide high-quality solutions without the need for complex heuristics. This paper explores the potential application of quantum annealing to optimize supply chain operations at Dell, specifically within their Excess & Obsolete (E&O) inventory process. The focus is on identifying a proactive re-balancing strategy for inventory management, minimizing costs, and improving parts distribution across Dell's global locations. By utilizing simulated annealing accelerated by high-performance computing (HPC) resources, including Nvidia GPUs and NEC's vector engine, we aim to achieve near-optimal solutions for inventory rebalancing. Some models will also be evaluated on quantum hardware to explore the feasibility of quantum acceleration in real-world supply chain optimization. Preliminary results suggest that while quantum annealing is still in its early stages, it holds significant promise for cost savings and operational efficiency in large-scale supply chains.

Keywords: *Quantum Annealing, Combinatorial Optimization, Inventory Repositioning*

1. INTRODUCTION

Modern optimization problems have two main routes to solution: exact solvers (brute force) and heuristic solvers. Each of these come with significant drawbacks – exact solvers can take extraordinary amounts of time for large problems, and good heuristics (necessarily customized to the problem) can take significant work to develop and don't produce optimal solutions. The reason for both of these blockers to quality solutions stems from the combinatorial explosion of the solution space when many variables are involved. In a problem where there are 5000 binary variables (a relatively modest size for many enterprise scale problems), the parameter space is a staggering 2^5000 elements (greater than 10^1500).

Quantum annealing is a technology that, while still maturing, promises to solve this problem by leveraging quantum bits (qubits) in superposition. In essence, this solves the combinatorial explosion problem by allowing the fundamental bits of calculation to explore the entire parameter space simultaneously, and so solutions can be found nearly instantly (on the order of nanoseconds). Currently, pure quantum annealers can handle ranges of up to 11,000 binary variables [1], and hybrid solvers go as high as 1M binary variables [2]. While they do not, in their current maturity, always return the absolute optimal solution, they produce high quality outcomes without the need for cumbersome heuristics.

The case presented here is from Dell, the large computer firm and their service parts operation which operates and manages millions of individual parts spread around multiple stocking locations stored around the world. The way Dell operates (a large, multinational company with thousands of sites and thousands of different part types) indicates the existence of a significant pain point, which is of significant interest to be improved using any available methods. We have identified a specific area of the supply chain within Dell that we believe will make an excellent candidate for quantum acceleration. This problem has to do with filling backstock of inventory at production sites by a combination of shipping overflow from other sites, purchasing additional product from suppliers, and identifying potential replacement parts for short stock.

2. METHODOLOGY AND RESULTS

Problem Statement: A subset of Dell's Excess & Obsolete inventory process monitors changes in parts demand, forecasts, or end-to-end costs of global locations which results in identification of part moves (candidate list), and could lead to non-optimal parts scrapping or disposing of parts ($10M currently out of $80M) quarterly.

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Solution: Determine a proactive re-balancing approach that determines a near-optimal solution where the objective function is to minimize total costs of candidates parts to be re-balanced by identifying "what parts are needed" and "where are they needed (locations)" in a Excess Report list of part & locations (from A to B) identified, with associated costs & lead times.

Simulated annealing will occur on Dell HPC servers (already available to Dell collaborators listed), including acceleration by Nvidia GPUs as well as NEC's vector engine card, for which there is a custom simulated annealing package called Vector Annealing [4]. Both ASU and Dell are in possession of such solutions. Some versions of the problem, possibly scaled down or "toy models", will also be evaluated by true quantum hardware, as the available qubit count of these machines allow.

3. CONCLUSIONS

The improvement of supply chains has the potential to save large companies millions to tens of millions of dollars a year. While quantum technology is still in its infancy, there is clearly great promise based on our initial structuring and simulation of results.

4. ACKNOWLEDGEMENTS

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