An Adiabatic Quantum Optimization Approach for the Mixed Integer Nonlinear Programming Problem

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Abstract : We present a method of using adiabatic quantum optimization (AQO) to solve a mixed integer nonlinear programming (MINLP) problem instance. The MINLP problem is a general form of a set of NP-hard optimization problems that are critical to many business applications. It requires optimizing a set of discrete and continuous variables with nonlinear and potentially nonconvex constraints. Obtaining an exact, optimal solution for MINLP problem instances of non-trivial size using classical computation methods is currently intractable. Current leading algorithms leverage heuristic and divide-and-conquer methods to determine approximate solutions. Creating more accurate and efficient algorithms is an active area of research. Quantum computing (QC) has several theoretical benefits compared to classical computing, through which QC algorithms could obtain MINLP solutions that are superior to current algorithms. AQO is a particular form of QC that could offer more near-term benefits compared to other forms of QC, as hardware development is in a more mature state and devices are currently commercially available from D-Wave Systems Inc. It is also designed for optimization problems: it uses an effect called quantum tunneling to explore all lowest points of an energy landscape where classical approaches could become stuck in local minima. Our work used a novel algorithm formulated for AQO to solve a special type of MINLP problem. The research focused on determining: 1) if the problem is possible to solve using AQO, 2) if it can be solved by current hardware, 3) what the currently achievable performance is, 4) what the performance will be on projected future hardware, and 5) when AQO is likely to provide a benefit over classical computing methods. Two different methods, integer range and 1-hot encoding, were investigated for transforming the MINLP problem instance constraints into a mathematical structure that can be embedded directly onto the current D-Wave architecture. For testing and validation a D-Wave 2X device was used, as well as QxBranch’s QxLib software library, which includes a QC simulator based on simulated annealing. Our results indicate that it is mathematically possible to formulate the MINLP problem for AQO, but that currently available hardware is unable to solve problems of useful size. Classical general-purpose simulated annealing is currently able to solve larger problem sizes, but does not scale well and such methods would likely be outperformed in the future by improved AQO hardware with higher qubit connectivity and lower temperatures. If larger AQO devices are able to show improvements that trend in this direction, commercially viable solutions to the MINLP for particular applications could be implemented on hardware projected to be available in 5-10 years. Continued investigation into optimal AQO hardware architectures and novel methods for embedding MINLP problem constraints on to those architectures is needed to realize those commercial benefits.

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