Efficient encoding of independent set optimization problems using QuEra’s neutral atom quantum computer
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Optimization is one of several areas where quantum computers could shine. Algorithms such as QAOA help efficiently search for solutions to optimization problems for a given target function and a set of constraints.

Independent set problems
One important class of optimization problems is the “Independent Set” (IS) problem, a combinatorial optimization problem that applies to a graph of vertices with connecting edges, as shown below:

![Graph of vertices and edges]

The graph might represent a cellular network with interconnected towers, a stock portfolio where an edge indicates a correlation between the connected stocks (vertices), or numerous other problems. An independent set is a set of vertices satisfying the constraint that no two vertices are connected. For instance, if red dots indicate the selected vertices, then the graph on the left does not depict an independent set (two red dots are connected by a vertex), whereas the graph on the right shows an independent set.

Maximum Independent Set problems
A subset of Independent Set problems is the Maximum Independent Set (MIS) problem. MIS seeks to find an IS with the maximum number of selected vertices (red dots). An example might be the placement of cellular antennas: a carrier wishes to place the
maximum number of antennas (vertices) as long as no two antennas interfere with each other (the presence of an edge encodes interference). Numerous other practical examples exist.

**Encoding constraints with neutral atoms**

QuEra’s quantum computer, Aquila, uses neutral atoms (Rubidium-87) that are held by laser beams in nearly arbitrary locations on a 2D grid. Up to 256 such atoms can be placed on the grid. Each atom can either be in a ground state |0> or the high-energy Rydberg state |r>. An important physical property is the “Rydberg Blockade” where an atom in the |r> state does not allow nearby atoms to also be in the |r> state.

Thus, instead of encoding the IS constraint using a mathematical function, Aquila users can encode these constraints geometrically. Users specify the physical location of atoms to correspond to the graph structure: placing atoms next to each other denotes an edge between them, and placing them far apart denotes the absence of an edge.

Once the atoms are placed, a series of excitation pulses can shift atoms in and out of Rydberg states, while allowing the physics to implement the constraints. The atom states are then read using a camera to obtain the result. This is shown in the middle picture below.

**Additional information**

For a more rigorous explanation and comparison with other quantum and non-quantum algorithms, see the S. Ebadi et al "Quantum optimization of maximum independent set using rydberg atom arrays," in Science.

To explore an efficient solution to other types of optimization problems, or to see if QuEra’s Aquila can be helpful to your research or production goals, contact us.