# Introduction to QUDO, Tensor QUDO and HOBO formulations: Qudits, Equivalences, Knapsack Problem, Traveling Salesman Problem and Combinatorial Games

## Authors

Alejandro Mata Ali

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## Abstract

This paper introduces Quadratic Unconstrained D-ary Optimization (QUDO), Tensor Quadratic Unconstrained D-ary Optimization (T-QUDO), and Higher-Order Unconstrained Binary Optimization (HOBO) formulations for combinatorial optimization problems. It explores their equivalences and illustrates their applications through examples such as the knapsack problem, traveling salesman problem, and various combinatorial games (Hashiwokakero, N-Queens, Kakuro, Inshi no heya, and Peg Solitaire). The aim is to provide a more accessible approach to these formulations for use in quantum or quantum-inspired optimization algorithms.

## Key Findings

* \* Introduced QUDO, T-QUDO, and HOBO formulations for combinatorial optimization.
* \* Showed equivalences between these formulations.
* \* Provided examples of these formulations applied to the knapsack problem, traveling salesman problem, and several combinatorial games.
* \* Demonstrated how QUDO can reduce required resources compared to QUBO.
* \* Highlighted limitations of QUDO in constraint implementation, which T-QUDO addresses.
* \* Showed how to implement QUDO in the QAOA formulation using qudit gates.
* \* Optimized the number of variables needed in the formulations for the presented examples.