Using a Quantum Genetic Algorithm to Optimize the Allocation of Cyber Security Budgets

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Abstract

Technological advancements highlight the importance of optimization problems, yet current models create slow and unreliable systems. However, the single-choice Knapsack problem can better model optimization scenarios where inputs are discrete and limited. In this paper, I propose a novel algorithm, Quantum Save, that uses quantum computing and genetic algorithms to optimize the Knapsack problem. With IBM's Qiskit Toolkit, Quantum Save begins by initializing a 32-qubit population and using the distribution from quantum measurement as inputs for the Knapsack problem. Reproduction over 10 generations is then simulated by adjusting probability amplitudes based on Knapsack output and implementing a disaster algorithm. After comprehensive testing of Quantum Save with different hyper-parameters, a probability amplitude reduction of 10% and a disaster-step of 5 generations was chosen. Quantum Save's uniqueness and hyper-parameter tuning resulted in a 49.2% improvement of Knapsack output compared to current implementations of quantum-genetic algorithms. To emphasize the efficacy of Quantum Save in real-world applications, this paper analyzes the algorithm's performance in allocating budgets of small firms. Using patterns in data collected from recent cyber attacks, Quantum Save suggested the implementation of specific controls to minimize company damages while remaining under budget. By analyzing the distribution of countermeasures selected at each budget range, there was strong evidence that Quantum Save increased mitigation from attacks. Also, Quantum Save scales linearly with $\mathcal{O}(n)$ complexity, making it fast and reliable. So, in the context of this case-study, Quantum Save harnesses the computational advantage of quantum computing to effectively optimize the Knapsack problem.