Exploring Quantum Computing for Solving the Traveling Salesman Problem

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Introduction: The Travelling Salesman Problem, a classic combinatorial optimization problem, seeks the Hamiltonian cycle that visits each city once and returns to the starting point. Traditional TSP algorithms fail because the number of cities exponentially increases the number of solutions. Quantum computing can now solve NP-hard problems. This study solves the TSP using QPE and IQFT. Our analysis replicates the 2018 study by Karthik Srinivasan, Saipriya Satyajit, Bikash K. Behera, and Prasanta K. Panigrahi on "Efficient quantum algorithm for solving traveling salesman problem: An IBM quantum experience."

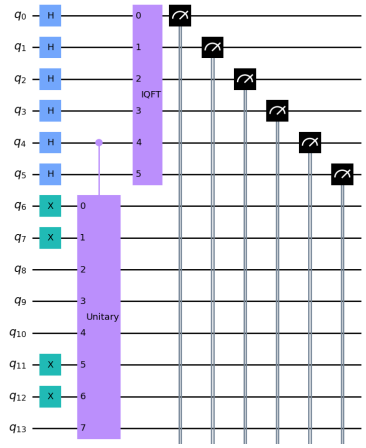

Figure 1. 14 Qubit Circuit

Methods: The distances between cities are encoded as quantum superposition phases. The phase estimation technique is used to learn how these phases are estimated, therefore providing the essential distance data needed to build a workable solution. The IQFT is the fundamental component of the quantum algorithm, as it effectively calculates distances from phase estimations. The IQFT decodes the phase-encoded distances and provides the exact distances required to choose the best path.

Results: We observed the 14-qubit circuit with all gates, including U4 and IQFT, implemented in the simulator. Bitstrings 1, 2, 3, 4, and 5, where the X gates are applied, match, according to the recorded measurements of classical bitstrings, however, bitstring 6 did not. The phases of the quantum state are estimates represented by these bit strings. The highest-counting bitstring represents the most likely phase value. The number of times with which a certain bitstring occurs is correlated with the probability that the corresponding phase (distance) is included in the TSP's optimum route.

Conclusions: The Inverse Quantum Fourier Transform and Quantum Phase Estimation Transform outperforms traditional techniques, demonstrating the possibility of quantum computing for optimization problems like the TSP. However, existing constraints in the implementation of qubits in practical quantum computers are obvious. Future advances may be able to overcome these limitations.

References:

1. Srinivasan, K., Satyajit, S., Behera, B. K., & Panigrahi, P. K. (2018, May 28). Efficient quantum algorithm for solving traveling salesman problem: An IBM quantum experience. arXiv.org. https://arxiv.org/abs/1805.10928v1 2. Wanti A. et al. Science. 2018;6(26):972-1018
2. I. (n.d.). Quantum phase estimation - IBM Quantum. IBM Quantum. https://quantum-computing.ibm.com/composer/docs/iqx/guide/quantum-phase-estimation

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