QuEST - Quantum Enhancement for Smart Transport

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Abstract: QuEST focuses on hybrid quantum–classical genetic algorithms for smart transport optimization, showing that quantum operators can improve traffic signal control and electric-vehicle energy management, especially under noisy quantum conditions.

This project investigates whether hybrid quantum–classical algorithms can improve the solution of complex optimization problems arising in Cooperative Intelligent Transport Systems, Smart Roads, and connected and automated mobility. Several relevant smart-mobility use cases were identified, including traffic signal control, eco-routing, emergency prioritization, and energy-aware transport management. The research focused on traffic engineering as a first validation domain, with the aim of designing quantum-enhanced methods that can be embedded into classical optimization workflows while improving search capability, robustness, and scalability for hard combinatorial problems.

The main methodological contribution is the development of two hybrid optimization strategies based on quantum genetic algorithms [1]. The first strategy involved a mono-objective genetic algorithm for Network Signal Setting Design (NSSD), where the target is the minimization of total deterministic traffic delay in a signalized network [2]. The second extends the same idea to a multi-objective formulation by integrating quantum operators into NSGA-II, enabling simultaneous optimization of traffic delay and electric-vehicle energy consumption and producing Pareto trade-offs between traffic efficiency and sustainability. Both strategies were implemented in Python using DEAP for evolutionary optimization and Qiskit for the quantum components.

Validation was carried out on simulated transport scenarios centered on an arterial network with two interacting signalized junctions. Traffic behavior was reproduced through traffic-flow simulation models, while the multi-objective setting incorporated energy estimates for connected and electric vehicles [3]. The quantum routines were tested on IBM ideal and noisy simulators. The results consistently showed that quantum-enhanced genetic algorithms are competitive with classical counterparts. In the mono-objective case, they improve delay minimization stability and the feasibility of generated solutions; in the multi-objective case, they produce well-distributed Pareto fronts with competitive or improved hypervolume. A particularly interesting outcome is that the main advantage does not emerge under ideal quantum simulation, but becomes evident on noisy backends, where the hybrid methods outperform the compared classical baselines in both average performance and variability across runs. This suggests that, in constrained optimization landscapes, quantum noise may help guide the search toward feasible and high-quality regions. Overall, the work demonstrates the promise of hybrid quantum evolutionary optimization for smart transport applications, while also showing that current benefits are most evident on small-to-medium test cases. The next major step is the transition from simulation to real superconducting quantum hardware through a gate-to-schedule translation layer developed in collaboration with the SQCLab at the University of Naples Federico II.

References

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