Quantum Backtracking in Qrisp applied to Sudoku Problems

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Montanaro's quantum backtracking algorithm is likely to provide a quantum speed-up for a class of classical optimization algorithms. Unaffected by Barren-Plateaus, this algorithm bodes well for the fault-tolerant era, as it requires only a limited number of arbitrary angle gates. Despite its potential, the algorithm has seen limited implementation efforts, presumably due to its abstract formulation. In this work, a detailed instruction on implementing the quantum step operator for arbitrary backtracking instances is provided. We also detail the process of constructing accept and reject oracles for Sudoku problems using our interface to quantum backtracking. The implementation is written in Qrisp, a high-level quantum programming language, making it executable on current quantum backends. As far as we are aware, this is the first instance of a compilable implementation of this generality, marking a significant and exciting step forward in quantum software engineering.

References

[1] R. Seidel, R. Zander, M. Petrič, N. Steinmann, et al., (to appear)
[2] A. Montanaro, Theory of Computing, 14 (2018) 1-24
[3] R. Seidel, N. Tcholtchev, S. Bock, M. Hauswirth, Lecture Notes in Computer Science (2023) 150-165

Figures

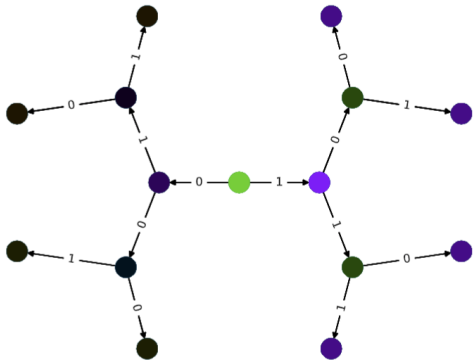

Figure 1: A binary backtracking tree in a state of superposition. Note that the 0-branch of the root is not explored, allowing more structured optimizations compared to Grover's algorithm.

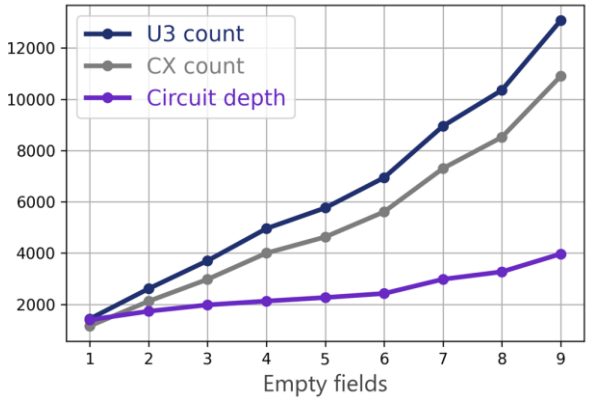

Figure 2: Calculated metrics of solving a 4x4 Sudoku puzzle with up to 9 empty cells.

Figure 3: Unsolved 4x4 Sudoku problem: A solution to this Sudoku with 9 empty fields is found on a simulator using the Qrisp implementation of Montanaro's algorithm with 91 qubits and circuit depth of 3968.

1		3	
3		1	
	1		3
4			